TITLE

UPGRADING OF HYDRAULIC CONTROL AND MONITORING SYSTEM OF A 500 TON HYDRAULIC PRESS

FINAL REPORT

BY

WESTINGHOUSE CANADA INC.

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ABSTRACT

A design is presented for upgrading the existing 500 ton hydraulic press at EMR's Physical Metallurgy Research Laboratory such that it will be suitable for performing basic research into forging operations. The design provides the capability for pre-programmed and repeatable controlled deformation schedules over a wide range of conditions (from <1% to >400% per second strain rates). The pertinent data are recorded during the deformation process for later plotting and analysis.

The design requires minimal modifications to the existing press or its hydraulic systems. An electric furnance capable of heating several test billets to controlled temperatures up to 1300°C and an induction heating unit capable of heating small billets in situ on the press to minimize heat losses have been included in the design.

RESUME

Un dessin est présenté pour ameliorer la presse hydraulique actuelle de 500 tonnes au Laboratoire de Recherche de Metallurgie Physique de EMR de façon à ce qu'elle soit convenable pour accomplir de la recherche de base dans les operations de la forge. Le dessin fournit la faculté de répeter des cycles de déformation controllées déja programmées sur un vaste assortiment de conditions (de <1% à >400% par seconde degré de contrainte). Les données pertinentes sont enregistrées pendant le processus de déformation pour être tracer et analyser plus tard.

Le dessin exige des modifications minimaux à la presse existante où ses systèmes hydrauliques. Un four électrique capable de chauffer plusieurs lingots d'épreuves pour des températures controller jusqu à 1300°C et un four d'induction capable de chauffer de petits lingots sur place sur la presse pour réquire au minimum les pertes de chaleur ont été inclus dans le dessin.

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1. INTRODUCTION

This report presents a design to upgrade the existing 500 ton hydraulic press at the Department of Energy, Mines and Resources, Physical Metallurgy Research Laboratory, to permit the capability of performing temperature and rate controlled forging operations.

The proposed design requires minimal modifications to the existing press. A new hydraulic ram capable of achieving the required performance specifications will be installed on the existing press along with completely new hydraulics and control systems. A programmable computer based data acquisition system which includes the necessary instrumentation for controlling, monitoring and recording temperature, pressure, load and deformation measurements will be provided.

A resistance heated furnace and an induction heating unit are provided for heating test billets to controlled temperatures up to 1300°C.

The design is intended to upgrade the existing press such that it will be suitable for performing basic research into forging operations where pre-programmed and repeatable deformation schedules (such as constant strain rate) are desired over a wide range of conditions, and measurement of the actual deformation schedule achieved is required.

The design of the new hydraulic ram, the oil supply and control systems, the instrumentation and data acquisition system and the billet heating equipment are described. The proposed fabrication schedule and estimated costs to perform the upgrading are given.

2. SPECIFICATIONS FOR UPGRADED PRESS

The anticipated performance capabilities of the upgraded press are:

i) Capable of forging billets up to 4 inches diameter by 5 inches high.
ii) Maximum design force of 450 tons (same as existing press).
iii) Capable of providing constant, pre-programmed strain rates from about

1% to over 400% (for 5 inch high billets) per second during deformation process, up to limit of 450 tons.

iv) Capability of stopping the ram rapidly in response to signal at critical point of deformation process.

v) Capability of up to 2 inches deformation of a 5 inch high billet.

vi) Capability of recording temperatures, hydraulic pressures, ram forces, ram displacement and various component strains at suitable time increments during deformation process.

vii) Capability of heating billets to predetermined temperatures over the range from 20°C to 1300°C.

viii) Suitable interlocks to ensure safety of operating personnel.

3. ASSESSMENT OF EXISTING PRESS

The assessment of the existing press was described previously in the Conceptual Design Report, CWTM-021-DN. Extensive modifications to the existing ram as well as the hydraulic supply and control systems would be necessary in order to achieve the desired performance. Even then, it was calculated that the minimum stopping distance of the existing ram, in response to a signal at the critical point during deformation, would be not be adequate.

At least eight proportional control valves, installed in a complex manifold on the top ram where the prefill valves are presently located, would be needed to achieve an oil flowrate of 8000 litres per minute, which would be required to obtain the maximum strain rate of about 400% per second. Additional smaller valves would be needed for the low strain rates. The maximum ram force would have to be de-rated significantly from the 450 tons due to the pressure drop through the proportional valves at the high strain rates. The present hydraulic lines for the oil supply and return would have to be replaced by larger lines to handle the high oil flowrates. The existing ram hydraulic seals would probably need to be replaced. The upper platen should be removed to minimize the momentum forces for operation at high ram speeds.

It was concluded that the existing ram and hydraulic system were not suitable for upgrading to meet the proposed requirements and that an alternative approach might be advantageous.

4. DESIGN OF NEW HYDRAULICS SYSTEM

4.1 General

The system proposed to replace the existing ram and hydraulics is shown schematically in Figure 1. The new ram is fastened on the lower bed plate of the existing press as shown in Figure 2. The upper platen is blocked in place at or near the top of its stroke and holds the die.

The ram was placed on the lower bed plate with the die above on the upper platen such that the ram working direction is upwards, rather than the more conventional downward stroke, in order to utilize gravity forces to optimize the stopping ability of the ram.

Hydraulic oil is supplied to the ram from an accumulator which is pressurized with air up to 4500 psi. The oil flowrate from the accumulator to move the ram is controlled by several proportional control valves which are selected in various combinations to provide the required range of flows. Poppet valves are provided to isolate the proportional valves, which do not seal tightly, and provide rapid starting and stopping of the oil supply. Poppet valves are also provided for venting, prefilling the ram, etc.

The new ram and hydraulic components were designed to operate at pressures up to 4500 psi (compared to about 2500 psi for the existing press) in order to minimize the ram size and oil volume requirements to facilitate the high ram speeds as well as stopping the ram. A high pressure hydraulic pump unit and a high pressure air compressor are provided for charging the system.

The operator will input the parameters desired to a programmable computer based data acquisition and control system which will then control the forging operation as well as record the actual conditions achieved. Independent manual controls and status indicators will be provided for general use during commissioning, maintenance, pre-test or post-test positioning, etc.

The various components are described in more detail in the following sections.

4.2 New Hydraulic Ram

The design of the new ram is shown in Figure 3. The overall dimensions of the ram housing allow the ram to be installed on the lower bed plate of the existing press (see Figure 2). The mounting flange on the bottom of the press should be dimensioned to suit the T-slots or available threaded holes in the bed plate.

The ram has a design working pressure of 4500 psi in order to reduce the piston diameter (16 inches) and still retain the capability of applying the maximum force of 450 tons. The top flange of the ram is bolted to allow easy maintenance for replacement of the seals and cap screws when necessary. The maximum travel of the piston is 8 inches.

The smaller piston diameter has less weight and requires less oil flow in order to minimize momentum and enhance the stopping ability of the ram. The lower oil flow requirements also reduce the number and/or size of the proportional flow control valves needed to provide the desired strain rates. The full design pressure of 4500 psi can be applied to the top side of the ram to assist stopping.

The new ram can be readily removed from the existing press by disconnecting the hold-down bolts and some short interconnecting pipes from the supply system.

4.3 Oil Delivery System

4.3.1 Control Valves

The locations of the various valves used in the hydraulic system are shown in the schematic in Figure 1. The type and model number of the valve used at each location is listed in Table 1.

To provide regulated oil flowrates over the range from 4 to 4000 litres per minute requires a total of six proportional valves with feedback control. The four largest valves (V3 to V6) are identical and are used in different

combinations to provide the oil flowrates over most of the range. Used together, they provide sufficient oil flow for the highest strain rates. The two smaller proportional valves (V1 or V2) provide the flowrates necessary at the low end of the range.

Poppet valves are placed in series with the proportional valves to provide isolation since the proportional valves do not seal tightly. These poppet valves also allow the slower responding proportional valves to be preset to a desired initial stroke position for the start of a deformation cycle. The poppet valve can then be opened rapidly, which is necessary for the high strain rates.

A poppet valve is also provided on the outlet of the ram to vent the oil as the ram moves upward. The valve is opened rapidly at the start of a deformation cycle and closed rapidly at a signal to stop the ram, in order to apply back pressure. Poppet relief valves are provided at the inlet and outlet of the ram to limit the pressure to 5000 psi. Poppet valves are included in the system for isolation of various components as well as manual control of the ram prior to and after a deformation cycle.

The poppet valves were selected for minimum pressure drop and minimum response time (approx. 10 ms). Technical details of the valves are provided in Appendix I.

4.3.2 Accumulator

A 25 U.S. gallon piston type accumulator designed for air/oil service at 4500 psi is recommended in order to supply the high flowrates of oil necessary to achieve the maximum strain rates. A piston type accumulator was chosen because of its inherent safety in the event that too much oil is removed. It is expected that the piston will respond "instantaneously" to the changes in oil flow required. The specifications for the accumulator are given in Appendix II.

4.3.3 Hydraulic Pump

The hydraulic system includes a high pressure oil supply pump with a 100 gallon reservoir, a filter and an oil return diffuser. The pump is capable of

delivering about 5 gpm of oil at pressures up to 5000 psi to permit adding oil to the accumulator while under pressure. Technical information is included in Appendix II.

4.3.4 Compressor

The compressor is capable of deliverying about 5.5 CFM of air at 5000 psi for pressurizing the accumulator. Dual moisture separators are included on the compressor to reduce the possibilities of oil contamination. The compressor will be isolated during a forging operation. Technical details of the compressor are given in Appendix II.

5. INSTRUMENTATION

Various instrumentation devices, as indicated in Figure 1, are provided to monitor and record the pertinent parameters during the deformation process. A programmable computer based data acquisition system scans and records the instrumentation signals as well as providing signals to the hydraulic valves to control the deformation rate and stop the ram at predetermined signals. The interconnections of the instrumentation, signal conditioning and data acquisition system are shown in Figure 4.

The ram position at any given time is measured using a displacement transducer connected between the upper and lower dies. The position and time information is used to compute the strain rate.

The oil pressure is measured at several locations in the hydraulic circuit using pressure transducers. The accumulator pressure and the pressure at the inlet to the ram should both be recorded throughout each deformation process. At the other locations, the pressures need not be measured for each deformation cycle since the information is required primarily during commissioning and initial trial runs. For routine press performance monitoring, we recommend the use of one pressure transducer and a valve manifold for selecting the measurement location.

Only the pressure measurement at the ram inlet is considered to require a

device with fast response since it is recommended that this signal be used to indicate the "critical" point in the deformation process where the press must be stopped as quickly as possible. A piezo-resistive type transducer was selected for this location and capacitance type pressure transmitters for the other locations.

The strain encountered by certain components, such as the die, can be measured using either weldable or bondable strain gauges attached to the component. It is not certain at this time which type of strain gauge would be most suitable or where it should be located. The devices described were chosen for general applicability. It may be desired to use other gauges for specific applications.

Up to 3 of the bolts holding the top flange of the ram will be replaced by special bolts with integral strain gauges. These will be monitored to assess the condition of the ram housing and if the strain indicated by these bolts exceeds a specified safety limit, the ram should be refurbished.

The accumulator oil level will be measured using a capacitance type level transmitter connected between ports near the top and bottom of the accumulator.

Temperatures of the furnace, work piece, dies or other components will be measured using standard Inconel sheathed, ungrounded Type K thermocouples.

If it is required to measure the ram force directly during a deformation process, then Bolt Force Sensors can be installed between the die and the upper platen to measure the net applied force at each hold down bolt during the deformation process. The total force is the sum of each of the sensors.

The proportional control valves incorporate an integral feedback signal to indicate the valve stroke position. The poppet valves also incorporate feedback devices to indicate the open or closed position.

The technical details and specifications for the various instrumentation devices are provided in Appendix III.

6. DATA ACQUISITION AND CONTROL SYSTEMS

A computer based data acquisition system will be used to control the operations of the hydraulic ram and gather all pertinent data during the deformation process. This equipment, except for the sensors attached locally, will be installed in an enclosed control room (described in Appendix III) which is located in front and to the side of the press as shown in Figure 2.

A supervisory program in the host computer is utilized by the operator to input the test parameters to permit prescheduling of the desired forging process. The supervisory program will prompt the user for the necessary information, such as desired strain rate and maximum deformation, billet geometry and other parameters needed to perform a specific deformation cycle. The supervisory program has provisions for using previous test histories stored on the hard disk in the system.

The host computer then performs all of the calculations needed by the data acquisition and control system for control of the ram and recording of the deformation history data. After the operator has reviewed and accepted it, this control information is down-loaded to the data acquisition and control system. The host computer initiates the test and then waits until the test is over to retrieve all of the data for permanent storage as well as printout, plotting and analysis.

For the high strain rates it is considered essential, and for other strain rates it is advantageous, to provide to the controller the "best estimate" of the valve stroke versus time history for a particular test. This enhances the feedback control of the proportional valves which may not have adequate response times for the highest strain rates. Therefore, in addition to calculating the ram position as a function of time from the input data, the estimated oil flowrate values versus time, the choice of valves required for the range of flowrates, the estimated stroke of the selected valves versus time and the initial pressure of the accumulator are determined. These values are based on the input data and the specified, or estimated, characteristics of the hydraulic components. These characteristics will be better defined during the commissioning of the systems.

All of the instrumentation and control signals are assigned to particular numbered channels together with their designations and associated conversion constants for converting the signals to engineering units.

After a deformation cycle has been performed, the host computer retrieves all of the test data for storage on the hard disk, along with an identifying header record. The data will then be printed out and plotted using available software packages from the computer supplier or custom developed software. The data can also be transferred using a serial link to other computer systems for archiving or further analyses.

The supervisory program, along with its documentation, is given in Appendix IV.

The data acquisition and control system, which performs the actual control functions and records the instrumentation signals, consists basically of microprocessor units which are described in detail in Appendix V. These units are capable of scanning and storing analog signals at rates up to about 12 kHz per channel. In order to achieve the fast cycle times required for the higher ram speeds, several units will be used in parallel with the input and output data channels grouped according to the scanning speed needed for those signals.

The signals required for feedback control of the proportional valves are connected to one unit, designated the controller, which contains the control algorithms. Essentially, this unit outputs the valve stroke position as a function of time. Initially, the values correspond to the estimated values down-loaded from the host computer. The ram position is monitored and compared to the expected value and if there is sufficient time to carry it out, the "estimated" values are corrected to maintain the strain rate as close as possible to the desired rate. Obviously, the slower the ram speed, or strain rate, the better the feedback control will be. In addition, the ofl pressure at the ram inlet is monitored and, upon detection of a specified drop in pressure, the isolating poppet valves are rapidly closed to stop the ram. The characteristics of this drop in pressure and the detection of it will have to be determined and refined during commissioning in order to obtain satisfactory results.

This unit is intended to perform control functions only and does not have provision for storage of other data during the test. The fastest cycle time, based on two analog inputs, one analog output and four digital signals, is estimated to be about 0.24 ms, if there is only very simple or no feedback control. This time increases as the feedback control calculations become more complex, or if more signals are added.

The second unit, designated the fast monitor, is used to record the instrument signals that require high speed monitoring, including the ram position and the ram inlet oil pressure signals which are connected to this unit as well as to the control unit. This unit has the same maximum scanning rate as the first unit, therefore, in order to obtain the same cycle time as the control unit at the high ram speeds (about 0.24 ms), a total of only three signals should be connected to this unit. If it is desired to scan other signals as rapidly as possible, such as strain gauge, ram force and pressure measurement signals and the position feedback signals for the proportional valves and the main flow isolation poppet valves, then an aditional fast monitor should be used. Otherwise, the remaining signals could be connected to the third (slow monitor) unit which is described below. The data are stored in a buffer and later transferred to the host computer.

The third unit, designated the slow monitor, is used to record the signals from the thermocouples as well as from the status indicators of the other poppet valves. This unit contains thermocouple compensation and has an estimated cycle time of about 15 ms. This scan speed is considered adequate since the temperatures are not expected to vary rapidly and the status of the valves is required only for reference since it will not change during a deformation process. This unit can also be used to scan the remaining signals not included above which do not require high scanning speeds. Again, all of the data are stored and later transferred to the host computer.

The software for the microprocessors in the data acquisition and control system must be custom developed by the supplier and it is anticipated that, particularly for the control unit, some refinements will be necessary during commissioning.

7. TEMPERATURE CONTROL OF BILLETS

There are two basic methods for heating the billets to controlled temperatures in order to assess the effect of temperature on material deformation. The choice of the most suitable method depends largely on the size of the billet. For large billets, an electric furnace is recommended for economic reasons. For smaller billets, up to about one inch diameter, the heat loss during transfer of the billet from the furnace to the press and the pause before the deformation is initiated would be unacceptable and an induction heating unit which would heat the billet in situ on the press is recommended. The two alternatives are described in the following sections.

7.1 Electric Furnace

An electric furnace with automatic temperature contol will be provided to heat test billets larger than about one inch diameter. The furnace will require approximately one hour to reach a soak temperature of 1300°C from ambient temperature, depending on the number of billets in the furnace. The furnace will be positioned to the front left of the existing press, (see Figure 2). The counter-balanced door on the furnace can be raised by activating a lever positioned on the floor in order to leave the operator's hands free to manipulate thermally insulated tongs for manual billet transfer from the furnace to the ram. The operator must wear suitable protective clothing such as face shield and gloves. Since billets may vary widely in geometry, manual transfer was selected to avoid the very high cost, for the anticipated frequency of use, of automating the process. Additional details of the furnace are provided in Appendix II.

7.2 Induction Heating Unit

An induction heating unit will be provided to heat test billets which are up to about one inch diameter. The unit will be provided with flexible leads to the induction coil so that the coil can be mounted on the press to heat the billet in situ. The time required to heat a billet from ambient to 1300°C will vary depending on the size of the billet, the design of the coil and the power rating of the induction unit chosen. In general, the billet should heat up in

about 5 to 10 minutes. The coil will be mounted on an arm that can be activated either manually or remotely (depending on cost considerations) to move the coil away from the ram just before the deformation process commences. The induction unit will be provided with an automatic temperature controller which uses an optical pyrometer for temperature measurement. The output signal of the optical pyrometer will also be monitored on the data acquisition system. Additional details of the induction unit are given in Appendix II.

8. OPERATING PROCEDURES

A User's Guide will be prepared which will describe in detail the operation of the equipment and the procedures to be followed for performing the forging process safely. A general outline of the procedures is given here to aid in understanding the rationale for the proposed design. The following sections will refer to the valve designations given in Figure 1.

8.1 Preparation

It is assumed the required die set has been installed on the press.

All of the instrumentation, signal conditioning and computer equipment should be turned on and allowed to warm up (about 1 hour) prior to performing a deformation test. The instruments should be checked to ensure they are functioning satisfactorily. The accumulator oil level transmitter should be equalized and checked for the zero value, as should the other pressure transmitters. Normally there is a zero offset value for these devices and the correct value must be stored by the supervisory program in the host computer. The thermocouple, strain gauge and valve position signals should be checked for the correct indication of the existing conditions. The values of the signals, except for the thermocouples, can be obtained from the Control Panel (see Figures 5) located in the control room. The thermocouples can not be connected to more than one device, therefore additional thermocouples must be installed in parallel for connection to the T/C monitoring panel (see Figure 6).

If the billet is to be forged at an elevated temperature and it is larger than about one inch diameter, it should be placed in the electric furnace with

the temperature control set to the desired temperature. Smaller billets will be placed directly in the press and heated using the induction unit.

The ram cavities should be already filled with hydraulic oil but satisfactory operation should be checked by manually stroking the ram up and down over a portion of its travel. The manual valve located at the front can be used for this purpose. This valve (V18) is a three-way valve which is spring loaded to return to the off position. Pushing the lever upwards opens the port to inject oil into the ram bottom cavity to raise the ram. A micro switch is activated at the same time to open valve (V12) to vent the top cavity. When the lever is pushed down, oil is injected into the top cavity and a micro switch activates valve V13 to vent the bottom cavity. Both valves V12 and V13 will be closed when the lever is in the off position.

Fill the accumulator (through valve V15) to approximately the mid point level. The valve can be operated manually from the Control and Monitoring Panel in the control room.

8.2 Deformation Process

After initial preparations have been completed, the operator will input all required data to the supervisory program in the host computer.

Charge the accumulator with air from the compressor (through valve V16) to the pressure estimated by the supervisory program for the desired strain rate.

If the billet is heated in the furnace, it should now be transferred to the die, after the keylock safety switch has been turned to the SAFE position. The billet should have a slight dish-shaped indentation in the centre on the bottom to match with a corresponding "bump" on the lower die half which is attached to the ram. The indentation is positioned over the bump on the die to ensure that the billet is centrally aligned. Once the billet is positioned, the keylock should be returned to the OPERATE position and the deformation process should be initiated as soon as possible to minimize cooling of the billet and heating of the bottom die. If the billet was heated by the induction unit, the coil should be moved away from the die, unless the die and coil have been

suitably designed to allow it to remain in place during the deformation cycle. As soon as the billet is in place on the die and the coil has been removed, if necessary, and the keylock switch is in the operate position, the deformation process can be initiated by the operator.

If all the systems checks were GO, and the control information has been down-loaded to the micro-computer, then the deformation process is ready to start as soon as the operator enters the command. The micro-computer control and monitoring systems are initiated simultaneously by the host computer.

The deformation process then proceeds automatically under control of the computer. The process can be terminated by the operator at any time by pressing the emergency stop button. The process can then be rescheduled with the control parameters changed. The operator must input the desired control information to the supervisory program in the host computer and restart, in the same manner as originally.

8.3 After Deformation

At the end of the deformation process, control is passed back to the host computer. The data stored by the two monitor units are transferred to the host computer and stored on a disk file along with a header file which identifies the test and the parameters.

The data can then be printed out at the desired time intervals or plotted to compare the actual strain achieved to the theoretical strain. The data can also be transferred via a serial communication link to another computer system for further processing or analyses.

8.4 Other Considerations

Dies will have to be suitably designed to operate satisfactorily on the new press. The bottom die half (male) must attach to the 10 inch diameter ram and have provision for attachment of one end of the linear displacement transducer which measures ram position. The overall length of this die half must be limited to suit the available space, leaving a sufficient gap between

die halves with the ram fully down, to insert the billet.

The top die half (female) must attach to the upper platen, which is blocked in place at (or near) the top of its stroke, or to an intermediate plate which is attached to the upper platen. The overall length of the die height must be limited to suit the available space leaving a sufficient gap for inserting the billet. If the ram force is to be measured directly using the force sensors, then accommodation for the sensors must be made in the die or intermediate plate, as illustrated in Figure 2. The force sensors should protrude, leaving a gap of about 1/16 inch.

9. SAFETY

Operation of the ram is performed primarily by the computer data acquisition system. A valve monitoring and control panel, shown in Figure 5, is provided which can be used to manually control all of the valves in place of the computer, particularly during commissioning phases. The valves are controlled remotely by either the computer or this panel and all valves have been specified to be in the "safe" condition with loss of power. The control of the valves will be connected through a keylock safety switch which, in the safe position, would prevent operation of the ram by either the computer or the manual control panel. This switch must be locked in the SAFE position whenever work is conducted at or nearby the press. Details of the safety switch are included in Appendix V. A stop button which will activate the switch to the safe position will be installed in the control room and near the press.

A safety shield of 1/8 inch sheet metal, containing a 12 inch by 12 inch double glass (Vycor and Infrared Pyrex) window for viewing will be installed across the front of the press for protection during forging operations. The shield will be mounted on guides so that it can be raised or lowered to allow access to the press to insert the billets. An interlock connected to the safety switch will prevent operation of the press unless the shield is in place.

Pressure relief valves (V10 and V11) are provided at the inlet and outlet of the ram to limit the pressures to below 5000 psi.

A manual control valve is provided at the front of the ram housing for raising or lowering the ram during pre- or post-test operations or maintenance. The lever is spring loaded to automatically return to the off position.

Since the ram is oriented to rise during its normal pressing operation, any leakage past the seals would tend to cause it to lower, which is considered not to be a hazard.

Some cap screws in the top flange of the ram have been replaced by strain gauged bolts which will indicate if the cap screws are overstressed and require changing.

The control program verifies that the hydraulic system status is satisfactory prior to initiating a test. The checks that are performed are described in more detail in Appendix IV.

10. COMMISSIONING

The complexities of the data acquisition and control system, the hydraulic systems and the instrumentation make it essential to perform extensive commissioning to ensure that the characteristics are sufficiently well established and the performance is satisfactory. It is expected that commissioning can be accomplished in two phases.

In the first phase, hydrostatic pressure tests, instrumentation calibrations and checkouts, refinement of the software for both the host computer and the control and monitor micro-computers will be accomplished. The equipment can be assembled and this work performed at the supplier's facilities. This will result in minimum disruption of the existing facility as well as minimizing costs.

For the second phase, the equipment must be moved to and installed on the existing press. Actual billet deformation tests over the full range of conditions will be performed to ensure all aspects of the system function satisfactorily as well as to characterize the behaviour of several of the

components. It is anticipated that the software, particularly the control algorithms, may have to be modified to optimize operation of the system.

After successful commissioning, a detailed User's Guide describing the system and operating procedures will be prepared.

11. RECOMMENDATIONS

The operation of the hydraulic ram at the higher strain rates depends to a large extent on the smooth operation of proportional valves V3, V4, V5 and V6. These valves are designed for a service pressure of 5000 psi (350 bar) and a nominal flow of 1600 L/min at about 600 psi pressure drop with single port operation. At the higher strain rates the valve pressure drop will be approximately 600 psi, which reduces the working pressure on the piston/ram and limits the deformation to materials with compressive yield strengths of approximately 130,000 psi or less (for the maximum geometry). The valve distributor has suggested that the valve manufacturer might be able to supply these valves double ported and suitable for 5000 psi service conditions. Double porting of the valves would reduce the pressure losses to approximately 150 psi instead of 600 psi. Also, these double ported valves would have better control characteristics with spool pressures equilized. At present, double porting the standard valve reduces the allowable service pressure to approximately 3600 psi (250 bar).

The number of instrumentation devices could probably be reduced to lower the overall cost significantly. It is recommended that only 9 strain gauge type devices, in addition to the pressure transducer at P4, be used. The measurement of the ram force directly using the force sensors is particularly expensive and the measurement of the force indirectly from the ram pressure might be adequate.

12. ESTIMATED COST

The estimated costs of performing the modifications to upgrade the existing press in accordance with the design presented in this report are given in Table 2.

The following items were not considered part of the scope of this work and were not included in the estimated costs:

i) Design and supply of dies and the intermediate support plate.

ii) Installation of electrical services.

iii) Provisions for blocking in place the upper platen.

iv) Construction of the control room.

13. SCHEDULE

The proposed schedule for performing the modifications is given in Table 3. It is anticipated that this work will require about 45 weeks for completion after receipt of an order.

TABLE 1: MODIFICATIONS TO 500 T PRESS - CONTROL VALVES REQUIRED

LOCATION	DES'N	TYPE	FLOW L/min	INPUT SIGNAL	FEEDBACK SIGNAL	SUPPLIER	CODE
OIL INLET	V1	PROP.	25	±10VDC	0-6VDC	HYMATIC	2FRE10/40/25L + VT-5004
OIL INLET	V2	PROP.	600	±10VDC	0-6VDC	HYMATIC	FE40C10/LM + VT-5011
OIL INLET	V3	PROP.	1600	±10VDC	+10VDC	HYMATIC	4WRDE32E520-30/10L2Z9D2M
OIL INLET	V4	PROP.	1600	±10VDC	+10VDC	HYMATIC	4WRDE32E520-30/ 10L2Z9D2M
OIL INLET	V5	PROP.	1600	±10VDC	+10VDC	HYMATIC	4WRDE32E520-30/ 10L2Z9D2M
OIL INLET	V6	PROP.	1600	±10VDC	+10VDC	HYMATIC	4WRDE32E520-30/10L2Z9D2M
OIL INLET	V7	POPPET	2400			HYMATIC	LC50A60/LFA50WEA
OIL INLET	V8	POPPET	12000			HYMATIC	LC125A20460/LFA125D20/F
CYLINDER VENT	V9	POPPET	8400			HYMATIC	LC100DB30E50/LFA100DBWA4G50/ 420/M-3SE10
CYLINDER SAFETY	V10	RELIEF	2400	-	-	HYMATIC	LC50DB40E60/LFA50DB460/400
CYLINDER SAFETY	V11	RELIEF	2400	-	-	HYMATIC	LC50DB40E60/LFA50DB460/400
CYLINDER VENT	V12	POPPET	200			HYMATIC	LC16A60/LFA16WEA/3SE6
PISTON VENT	V13	POPPET	200			HYMATIC	LC16A60/LFA16WEA/3SE6
OIL VENT	V14	POPPET	200			HYMATIC	LC16A60/LFA16WEA/3SE6
OIL PUMP SAFETY	V15	POPPET	200			HYMATIC	LC16A60/LFA16WEA/3SE6
COMPRESSOR SUPPLY	V16	POPPET	200			HYMATIC	LC16A60/LFA16WEA/3SE6
ACCUMULATOR VENT	V17	POPPET	200			HYMATIC	LC16A60/LFA16WEB/3SE6
RAISE RAM	V18	PROP.	25	MANUAL			
LOWER RAM	V19	PROP.	25	MANUAL			

TABLE 2: COST ESTIMATE

Supply and assemble hydraulic components		$146,000
Instrumentation, including calibration		
Pressures, Temperatures, etc.		22,000
Strain Gauges		20,000
Force Sensors		14,000
Data Acquisition and Control System		
Host Computer		25,000
Micro-computers (TAURUS)	- Hardware	35,000
	- Software	39,000
Temperature Controlled Billet Heating		
Electric Furnace		17,000
Induction Heater (5kW)		25,000
Remote Positioning of Induction Coil		10,000
Engineering, Liaison, Commissioning, Shipping		34,000

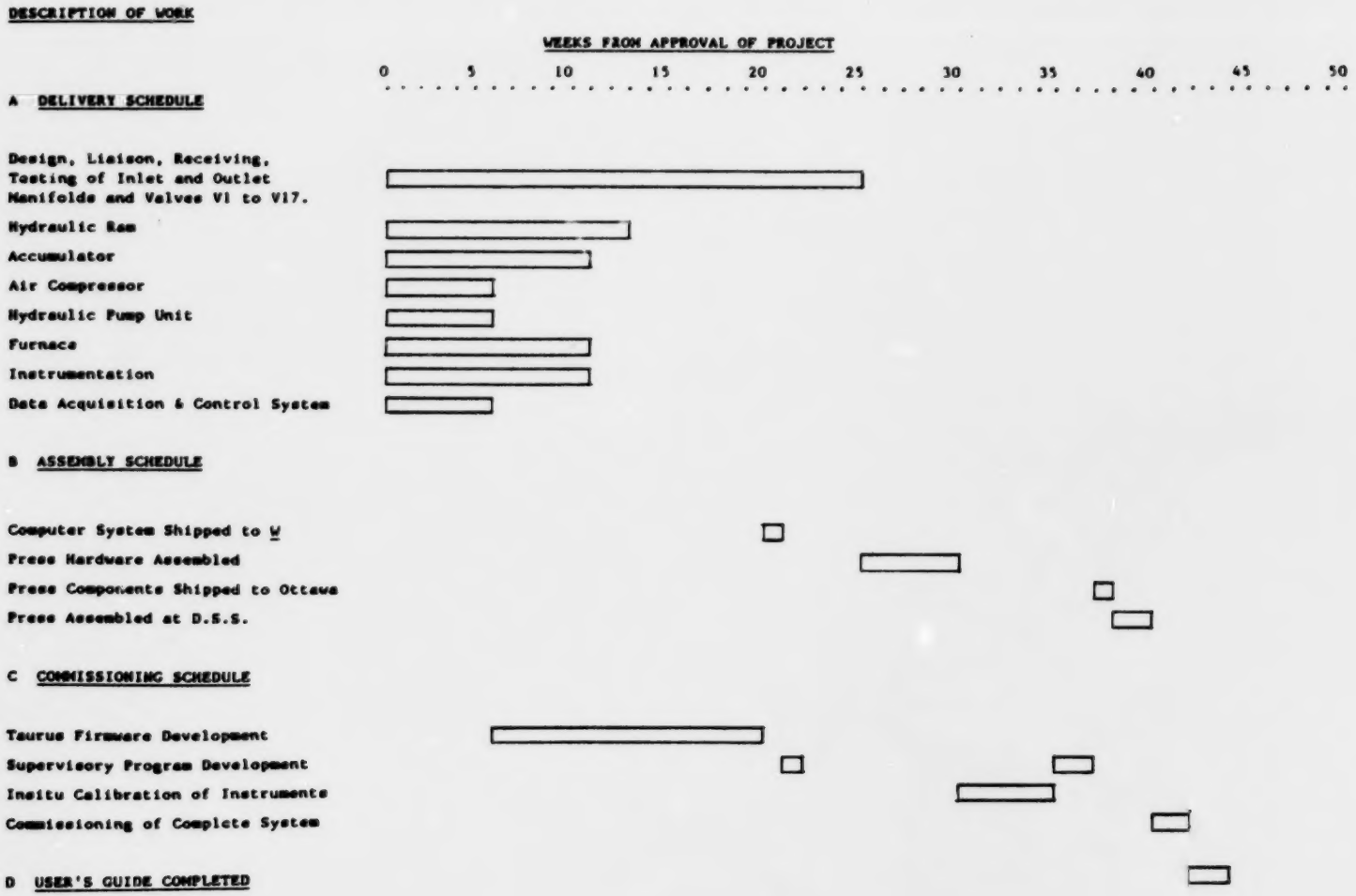


TABLE 3 FABRICATION SCHEDULE

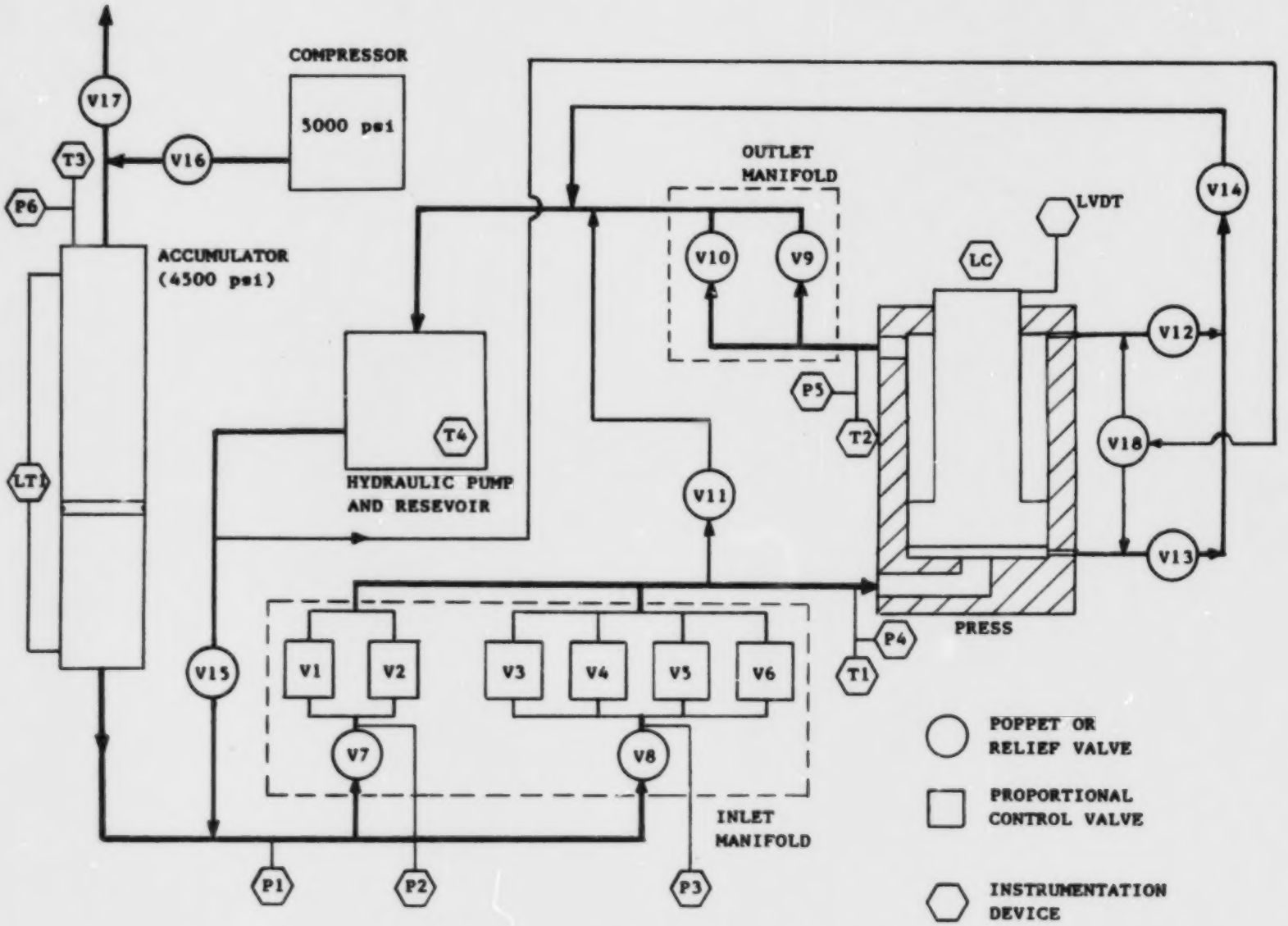
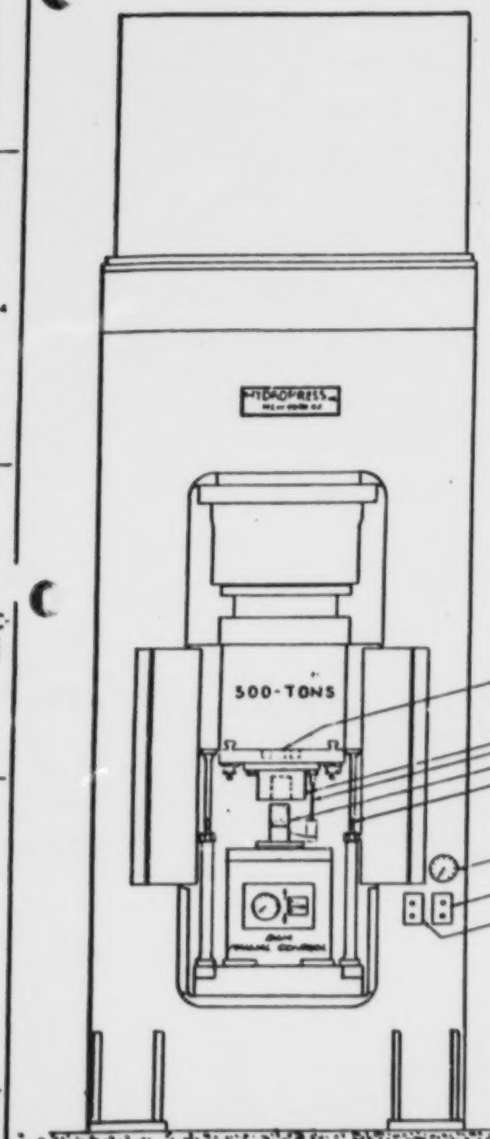
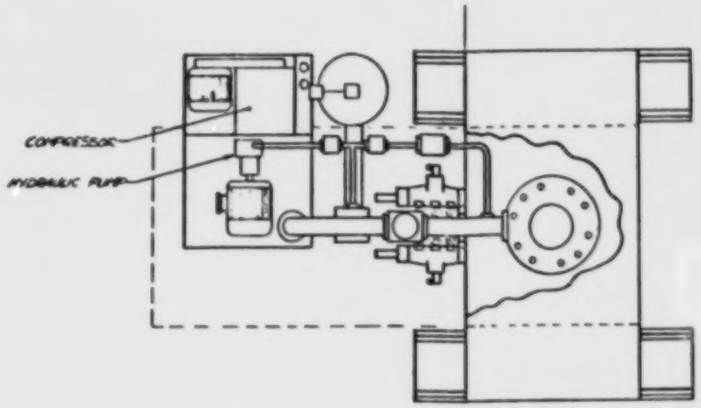


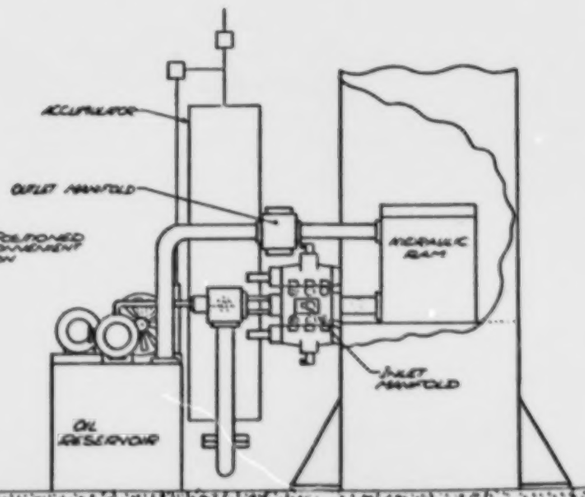
FIGURE 1 SCHEMATIC OF PRESS HYDRAULIC SYSTEM AND INSTRUMENTATION



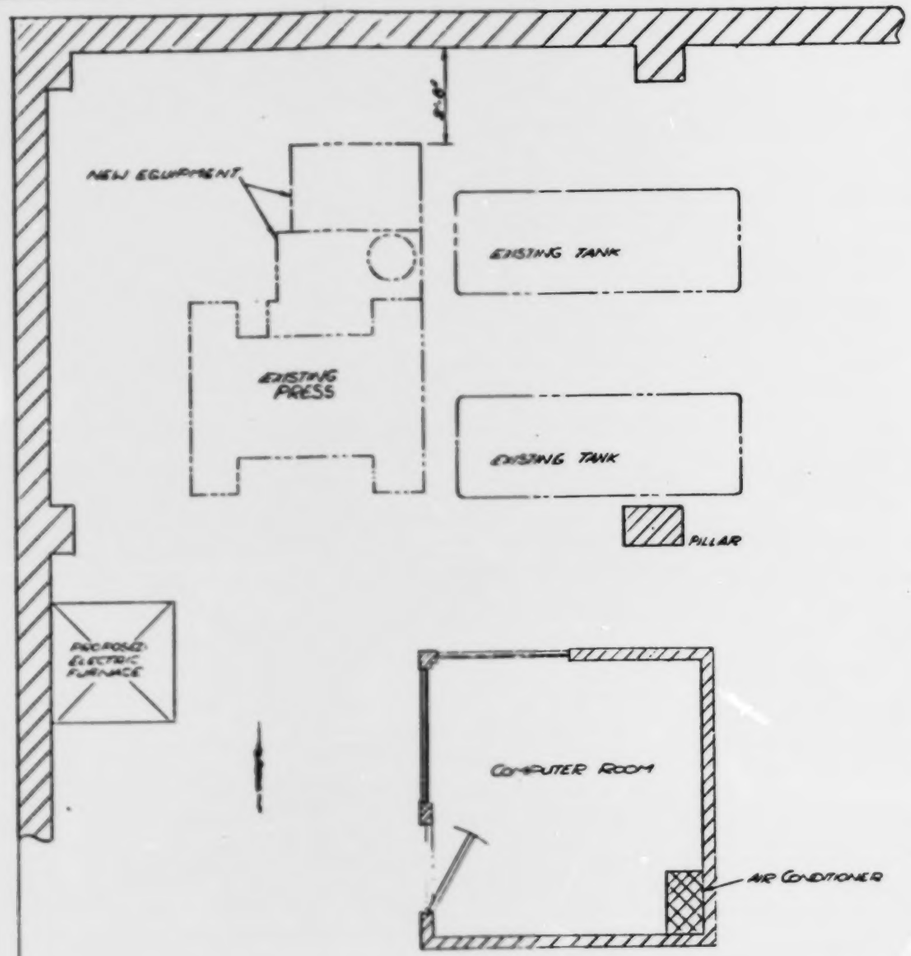
FRONT VIEW



TOP VIEW



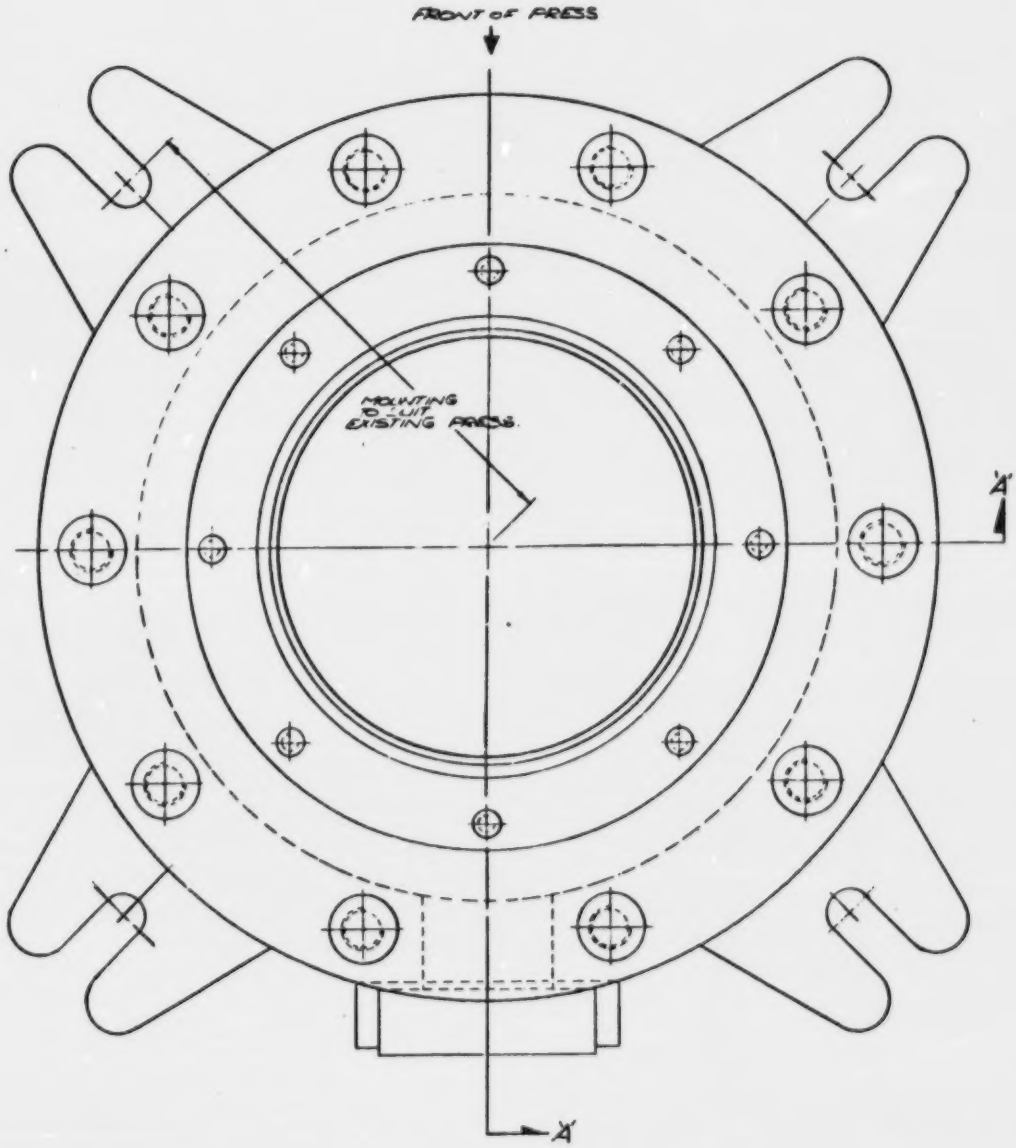
SIDE VIEW



FLOOR LAYOUT

FIGURE 2 LAYOUT OF PRESS

Westinghouse Canada Inc.
MODIFIED 500 TON HYDRAULIC PRESS
GENERAL ARRANGEMENT
3773D52


FRONT OF PRESS
MOUNTING TO SUIT EXISTING PRESS
A
A
19.0" DIA.
21.0" DIA.

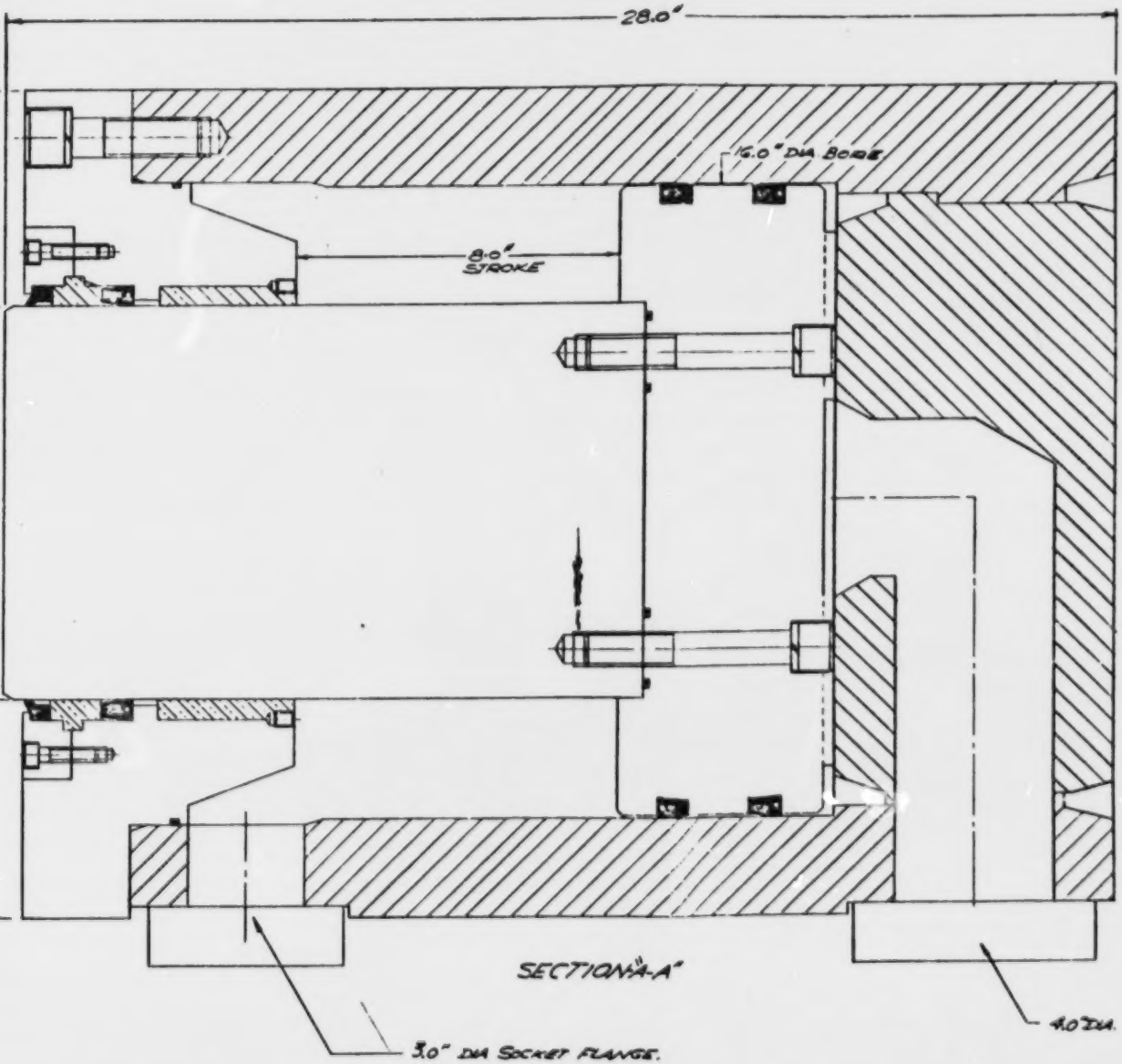


FIGURE 3 RAM DETAIL

Westinghouse Canada Inc.
MODIFIED 500 TON HYDRAULIC PRESS
PROPOSED LAYOUT FOR "HYDRAULIC RAM"
SCALE
3773 D 54

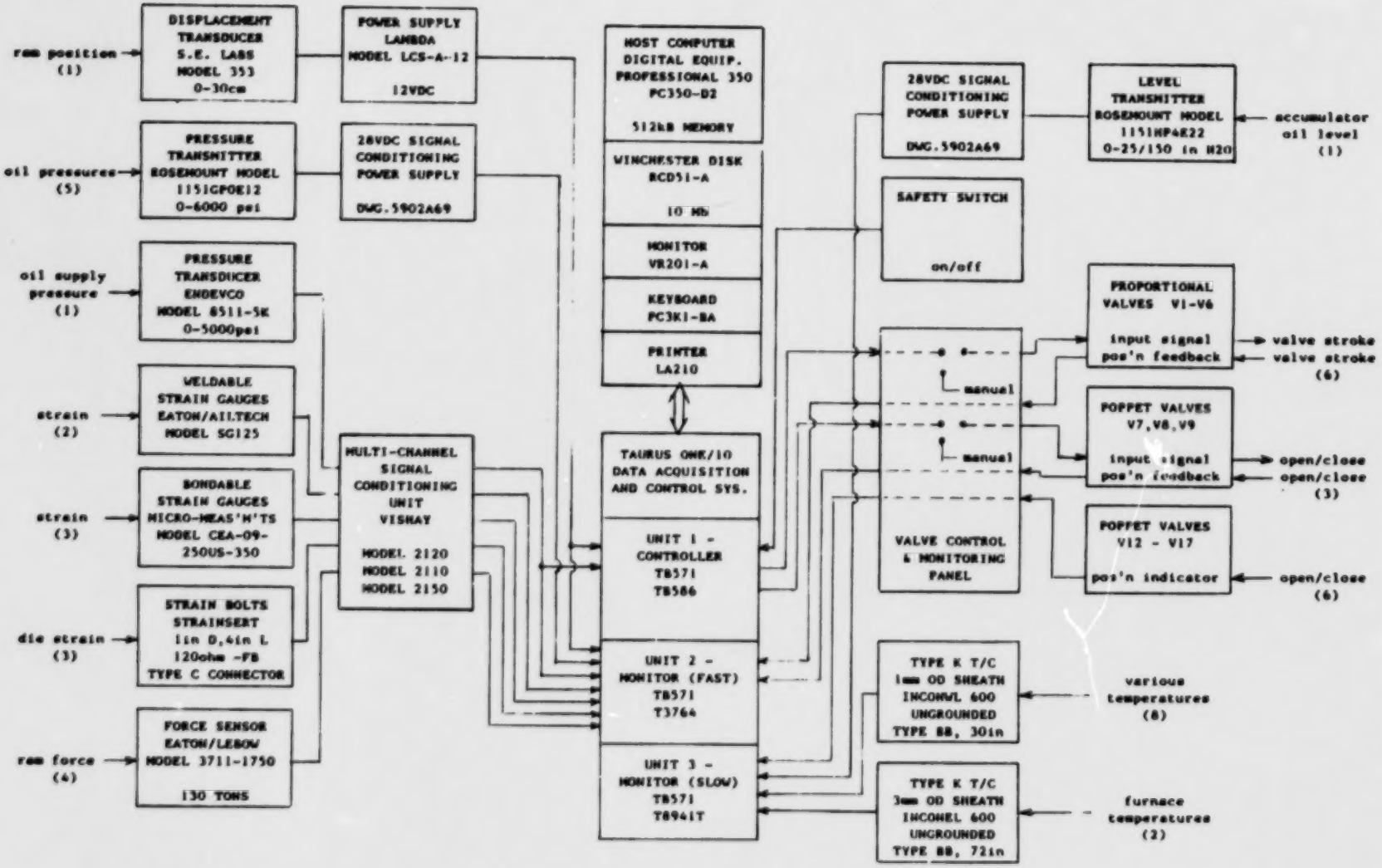
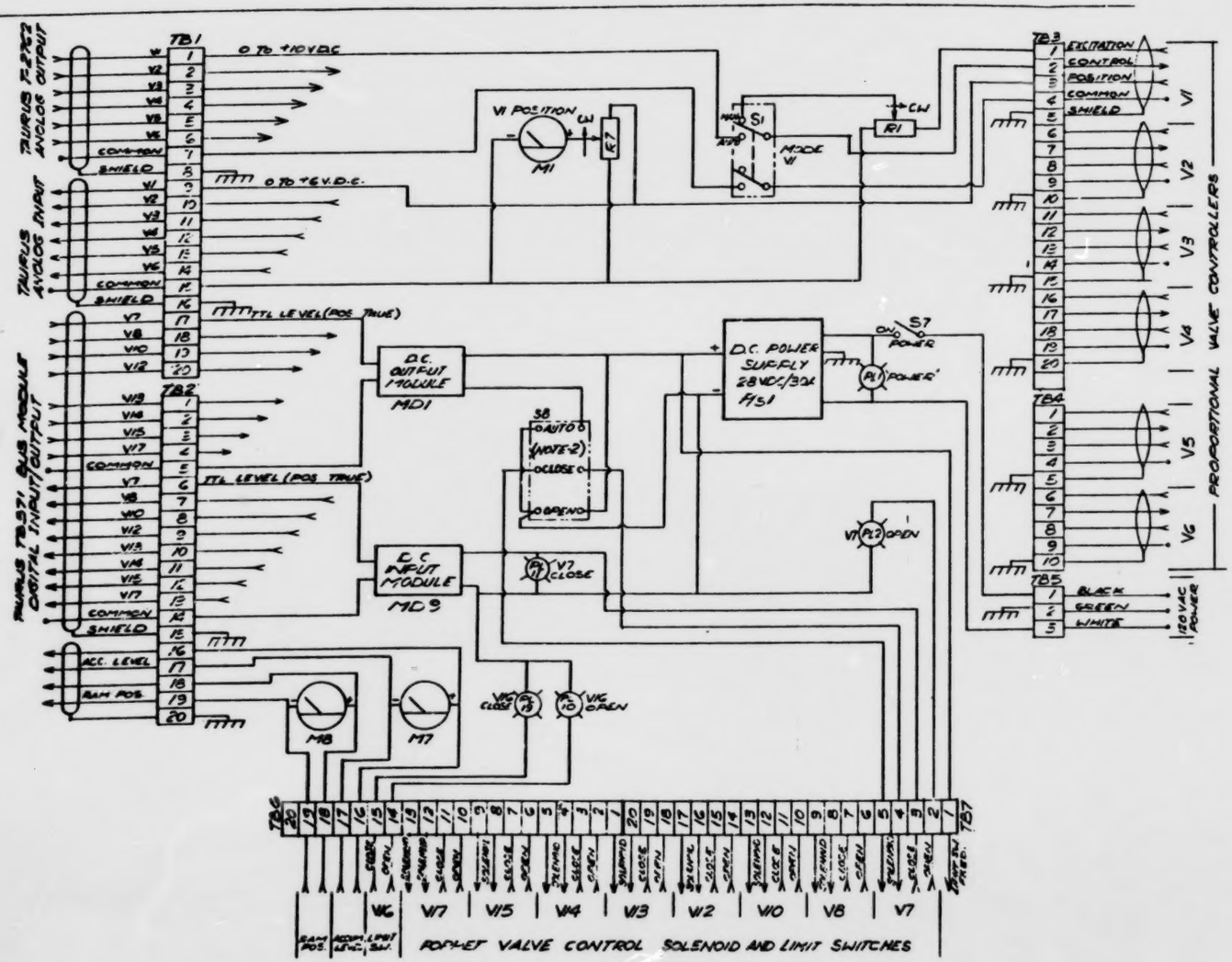
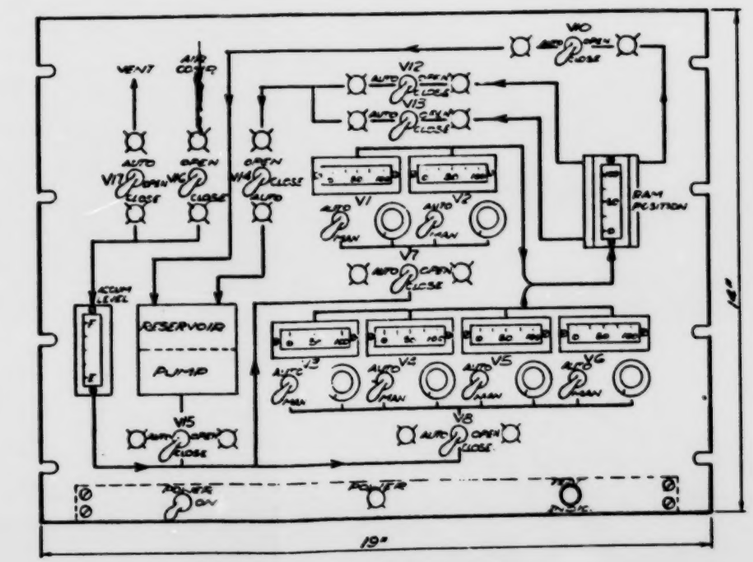

ram position (1)
DISPLACEMENT TRANSDUCER S.E. LABS MODEL 353 0-30cm
POWER SUPPLY LAMBDA MODEL LCS-A-12 12VDC
oil pressures (5)
PRESSURE TRANSMITTER ROSEMOUNT MODEL 1151GP0E12 0-6000 psi
28VDC SIGNAL CONDITIONING POWER SUPPLY DWG.5902A69
oil supply pressure (1)
PRESSURE TRANSDUCER ENDEVCO MODEL 8511-5K 0-5000psi
strain (2)
WELDABLE STRAIN GAUGES EATON/AILTECH MODEL SG125
strain (3)
BONDABLE STRAIN GAUGES MICRO-MEAS'M'TS MODEL CEA-09-250US-350
die strain (3)
STRAIN BOLTS STRAINSERT 1in D,4in L 120ohm -FB TYPE C CONNECTOR
ram force (4)
FORCE SENSOR EATON/LEBOW MODEL 3711-1750 130 TONS
MULTI-CHANNEL SIGNAL CONDITIONING UNIT VISHAY MODEL 2120 MODEL 2110 MODEL 2150
HOST COMPUTER DIGITAL EQUIP. PROFESSIONAL 350 PC350-B2 512kB MEMORY
WINCHESTER DISK RCD51-A 10 Mb
MONITOR VR201-A
KEYBOARD PC3K1-BA
PRINTER LA210
TAURUS ONE/10 DATA ACQUISITION AND CONTROL SYS.
UNIT 1 - CONTROLLER TB571 TB586
UNIT 2 - MONITOR (FAST) TB571 T3764
UNIT 3 - MONITOR (SLOW) TB571 T8941T
28VDC SIGNAL CONDITIONING POWER SUPPLY DWG.5902A69
SAFETY SWITCH on/off
manual
manual
VALVE CONTROL & MONITORING PANEL
LEVEL TRANSMITTER ROSEMOUNT MODEL 1151HP4R22 0-25/150 in H20
accumulator oil level (1)
PROPORTIONAL VALVES V1-V6 input signal pos'n feedback
valve stroke
valve stroke (6)
POPPET VALVES V7,V8,V9 input signal pos'n feedback
open/close
open/close (3)
POPPET VALVES V12 - V17 pos'n indicator
open/close (6)
TYPE K T/C 1mm OD SHEATH INCONEL 600 UNGROUNDED TYPE BB, 30in
various temperatures (8)
TYPE K T/C 3mm OD SHEATH INCONEL 600 UNGROUNDED TYPE BB, 72in
furnace temperatures (2)

FIGURE 4 INSTRUMENTATION BLOCK DIAGRAM

NOTES:
1. V1; V8; V10; V12; V13; V16; V18 ARE POWER TO OPEN.
2. V17 IS POWER TO CLOSE
3. R1 & R7 ARE ADJ. TO SCALE POSITION SIGNAL
4. 'TEST INDICATOR' - CIRCUITRY NOT SHOWN
5. W CIRCUITRY SHOWN; TYPICAL OF V2 TO V6
6. V7 CIRCUITRY SHOWN; TYPICAL OF V8; V10; V12; V13; V16 & V18

ITEM	QTY	DWG NO	DEVICE NO	DESCRIPTION	MANUFACTURER
1		1		PANEL - HAMMOND	1590 BOMBAY
1		2		ENCL. 3-ALUMINUM - HAMMOND	1444-3
7		3	M1-M7	METER - 2" METER; 0-5 V.D.C.; 750Ω; SQUARE BEZEL SERIES	3104
1		4	M8	" ; 0-10 V.D.C.	3107
6		5	R1-R6	POTENTIOMETER-( ) BOURNS PRECISION	3540S-1-103
6		6		KNOB - KNOB FOR JT 5 - KURZ	560-3L
6		7	R7-R12	MINIATURE POTENTIOMETER (500Ω) - REC	3540S011
7		8	S1-S6-1NG	ROTARY SWITCH - 2 P.D.T.	52223L
1		9	S7	"	52221L
8		10	S8-S15	"	52221L
5		11	TB1-3-6-7	TERMINAL BLOCK - CINCH JONES	2D-61
1		12	TB4		10-61
1		13	TB5		3-61
1		14	PL1	L.E.D. INDICATOR (AMBER)	1222SCB
9		15	PL2-10	(GREEN)	1222SCB-28V
9		16	PL11-19	(RED)	1222SCR-28V
9		17	MD1-8	CRYDOM DC OUTPUT MODULE (INPUT-TTL) (OUTPUT-3.5A @ 60VDC	63C1A
8		18		MOUNTED BUS FOR JT. #17	MS4 (SINGLE)
9		19	MD9-16	CRYDOM D.C. INPUT MODULE	61C1A
8		20		MOUNTED BUS FOR JT. #19	MS16
1		21	P/S 1	LAMBDA POWER SUPPLY - 28VDC ± 5% @ 2.8 AMPS @ 40°C; LNR-28-MB	LMS-28-MB



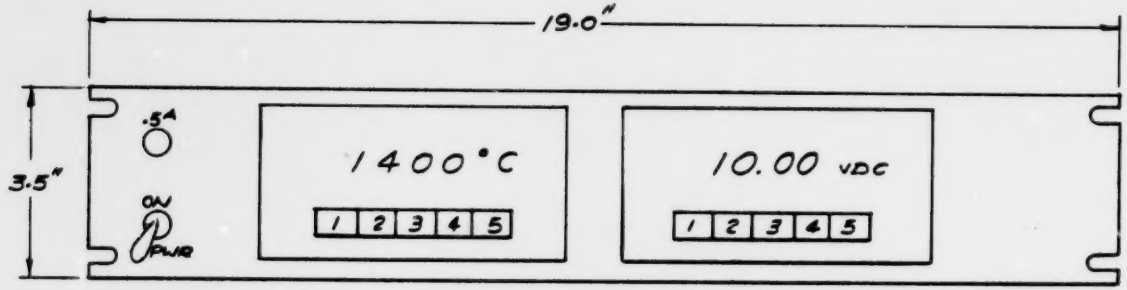


FRONT PANEL LAYOUT

FIGURE 5 VALVE MONITORING PANEL

Westinghouse Canada Inc.
PACIFIC ECCO IN HYDRAULIC PRESS
VALVE CONTROL & MONITORING PANEL-LAYOUT & SCHEMATIC
SCALE
3773 D 53

MANUFACTURING SYMBOL							DESCRIPTION	
				1		1	DORIC THERMOCOUPLE INDICATOR (5 INPUTS)	
							TYPE K T/C (-199°C TO 1400°C)	*402A-K-C
				1		2	RACK MOUNT ADAPTOR (2 OUTPUTS)	OWG (2)
				1		3	DORIC VOLTAGE INDICATOR (5 INPUTS)	
							-LINEAR VOLTAGE INPUT - RANGE -10V TO +25 V.	
							-RESOLUTION 10 mV. -ACCURACY 0.01% ± 1 COUNT	*402A-MM



Westinghouse Canada Inc.

TITLE MODIFIED 500 TON HYDRAULIC PRESS

DISPLAY PANEL - TEMPERATURE/PRESSURE.

SCALE

DRAWN BGL 87

APP. BY

CHECKED

APP. BY

CHECKED

APP. BY

785 B 748

FIGURE 6 THERMOCOUPLE READOUT PANEL

APPENDIX I

SPECIFICATION SHEETS FOR HYDRAULIC VALVES

V1	- Proportional Valve	Product Bulletin RA29190
	Amplifier	VT-5004
V2	- Proportional Valve	Product Bulletin RE29203
	Amplifier	VT-5011
V3-V6	- Proportional Valves	Product Bulletin RE29104
	Amplifier	VT-1610
V7,V10,V11	- Poppet Valves	Product Bulletin RA81062
V8	- Poppet Valve	Product Bulletin RA81074
V9	- Poppet Valve	Product Bulletin RE81071
V12-V17	- Poppet Valves	Product Bulletin RA81050

REXROTH
WORLDWIDE HYDRAULICS
MOBILE HYDRAULICS DIVISION
Wooster, Ohio
216/262-2010
▷ INDUSTRIAL HYDRAULICS DIVISION
Bethlehem, Pa.
215/694-8300

ELECTRONIC PROPORTIONAL PRESSURE COMPENSATED FLOW CONTROL VALVE TYPE 2 FRE/SERIES 40

RA 29190

SIZES 10 (1/2") 16 (3/4")	UP TO 4800 PSI (315 BAR)	UP TO 42.2 GPM (160 L/MIN)	ISSUED: 3-83

- With Pressure Compensator for Control of Flow Independent of Pressure Differential
- Operation by Proportional Solenoid
- With Electronic Positional Feedback of the Control Orifice
- Both valve and control electronics available from Rexroth

2 FRE...-40

DESCRIPTION OF FUNCTION, CROSS SECTION

Proportional flow control valves type 2 FRE are 2-way valves. They allow a preset electrical signal to control flow independent of pressure and temperature variation.

The assembly consists of a housing (1), a proportional solenoid with inductive positional transducer (2), measuring orifice (3), pressure compensator (4), together with stroke limiter (5) and optional reverse flow check valve (6).

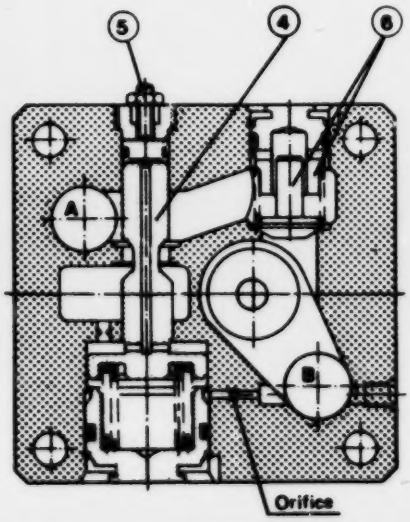
The oil flow required is set using a potentiometer, which in turn gives an input value to amplifier type VT-5004. Refer to RA 29945. This in turn controls the orifice via the proportional solenoid. The position of the orifice is determined by the inductive positional transducer, and any difference from the given input value is then corrected by the control system.

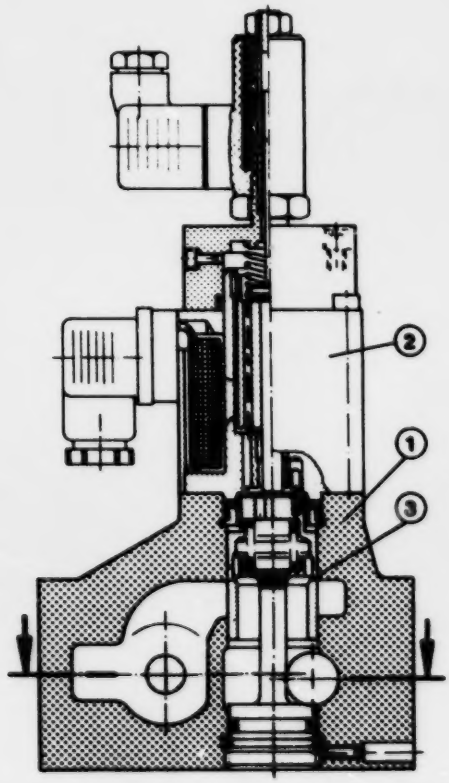
The pressure drop across the measuring orifice is held constant by the pressure compensator. The oil flow is therefore independent of load.

The low temperature drift is achieved by a sharp edge orifice design. At an input level of 0, the measuring orifice is closed. In the event of electrical failure, the measuring orifice closes.

A smooth start is possible from the input value 0. The orifice may be opened and closed gradually by two ramps in the electronic amplifier.

Free flow from B to A is possible via the check valve (6).

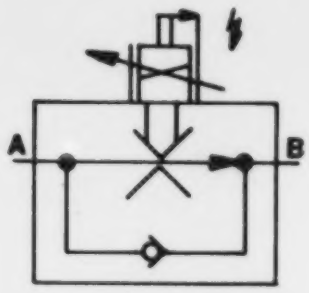




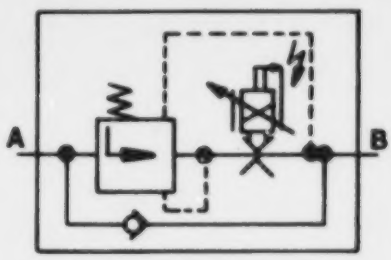
SYMBOLS

RA 29190

Simplified Proportional Flow Control Valve



Complete Symbol for Proportional Flow Control Valve



ORDERING CODE

2 FRE 16 – 40 / 160L B V •

SIZE
10 = Size 10 (1/2")
16 = Size 16 (3/4")

DESIGN SERIES
Numbered 40 to 49. Installation and connection dimensions remain the same.

FLOW RATE/ORIFICE LETTER

Further Details In Clear Text

SEALS
Omit = Buna-N
V = Viton

STROKE LIMITER
Omit = Without stroke limiter on pressure compensator
B = With stroke limiter on pressure compensator

FLOW RATE A TO B

SIZE 10			SIZE 16
Linear	Progressive	2-Stage Progressive (See Curve, Page 5)	Linear
5L = To 1.3 GPM (5 l/min)	5Q = To 1.3 GPM (5 l/min)	2QE = To 0.53 GPM (2 l/min)	80L = To 21.1 GPM (80 l/min)
10L = To 2.64 GPM (10 l/min)	10Q = To 2.64 GPM (10 l/min)	5QE = To 1.3 GPM (5 l/min)	100L = To 26.4 GPM (100 l/min)
16L = To 4.2 GPM (16 l/min)	16Q = To 4.2 GPM (16 l/min)		125L = To 33.0 GPM (125 l/min)
25L = To 6.6 GPM (25 l/min)	25Q = To 6.6 GPM (25 l/min)		160L = To 42.2 GPM (160 l/min)
50L = To 13.2 GPM (50 l/min)			
60L = To 15.8 GPM (60 l/min)			

TECHNICAL DATA

RA 29180

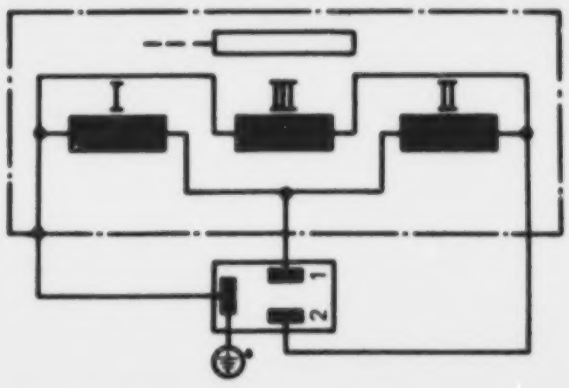
HYDRAULIC

Operating Pressure, Port A			4600 PSI (315 bar)								
Minimum Differential Pressure			Size 10 (1/2")						Size 16 (3/4")		
			43 - 116 PSI (3 to 8 bar)						87 - 145 PSI (6 to 10 bar)		
Differential Pressure For Free Flow B to A	Orifice Open	PSI (bar)	14 (1)	12 (1.2)	22 (1.5)	29 (2)	44 (3)	50 (3.5)	23 (1.6)	28 (1.9)	35 (2.4)	45 (3.1)
	Orifice Closed	PSI (bar)	25 (1.7)	29 (2)	36 (2.5)	44 (3)	73 (5)	87 (6)	44 (3)	52 (3.6)	65 (4.5)	87 (6)
Flow Q_{max}	Linear + Progressive	GPM (l/min)	1.32 (5)	2.6 (10)	4.23 (16)	6.61 (25)	13.2 (50)	15.8 (60)	21.1 (80)	26.4 (100)	33.0 (125)	42.2 (160)
	2-Stage Progressive	GPM (l/min)	10.5 (40)									
Flow Characteristics	Temperature Drift Hydraulic + Electrical $\Delta Q/^{o}C$		0.1% of Q_{max}									
	Pressure Stability (to Δp = 4600 psi (315 bar)		$\pm$ 2% of Q_{max}									
Filtration (For Increased Life)			10 micron									
Fluid			Petroleum based hydraulic fluids, phosphate ester									
Fluid Temperature Range			-4 to 158°F (-20 to 70°C)									
Viscosity Range			35 to 1750 SSU (2.8 to 380cSt)									
Hysteresis			< $\pm$ 1% of Q_{max}									
Repeatability			< 1% of Q_{max}									
Mounting Position			Optional									
Typical Overall error	2 FRE		< $\pm$ 2%									
	Amplifier VT-5004		< 0.5%									

ELECTRICAL

Type of Supply		Direct Current (DC)		
Solenoid Coil Resistance	Cold at 20°C	10 ohms		
	Maximum Value, Warm	13 9 ohms		
Coil Rating		Continuous		
Maximum Ambient Temperature		122°F (50°C)		
Electrical Connections	Solenoid	Plug-in Connector, type Z4		
	Positional Transducer	Plug-in Connector		
Insulation		Exceed Nema class B requirements		
Control Amplifier		VT5004	Note: A regulated power supply is recommended	
Maximum Power Requirement		50 watts		
Coil Resistance at 68°F (20°C) (Positional Transducer)		I	II	III
		56 ohms	56 ohms	112 ohms
Inductance (Positional Transducer)		6 to 8 mH		
Transducer Carrier Frequency		2.5 kHz		

POSITIONAL TRANSDUCER



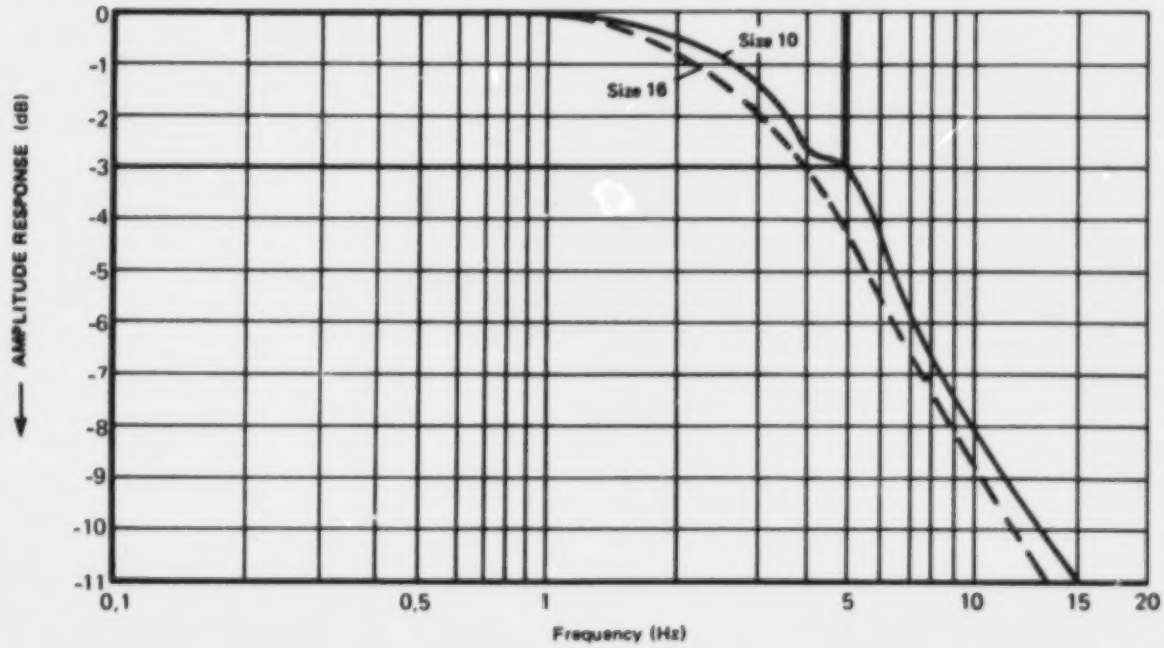
*Denotes pin marking in connector, connect to amplifier, DO NOT GROUND.

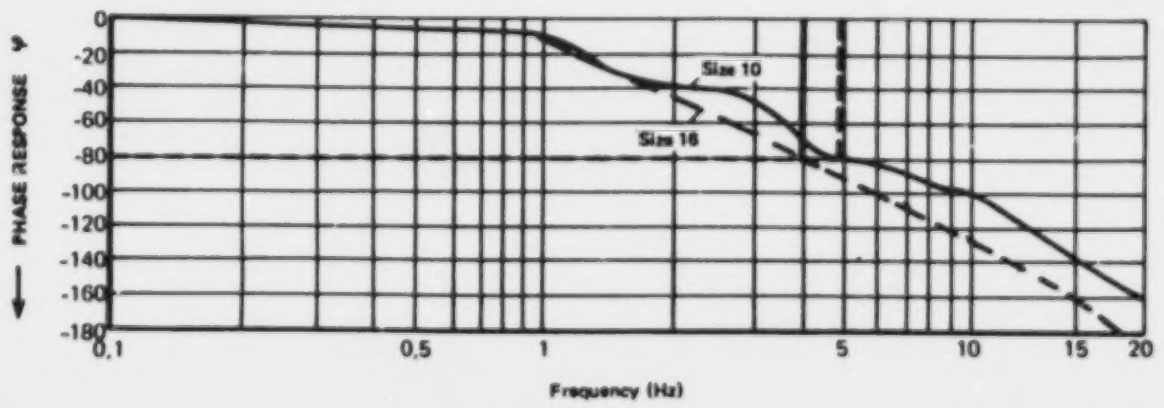
FREQUENCY RESPONSE (Measured at 122°F (50°C), P_{inlet} = 725 PSI (50 bar), Amplitude 0-100%, Size 10 (80 L Orifice/Size 16 (160 L Orifice)

RA 29190

Dynamic Characteristics Table

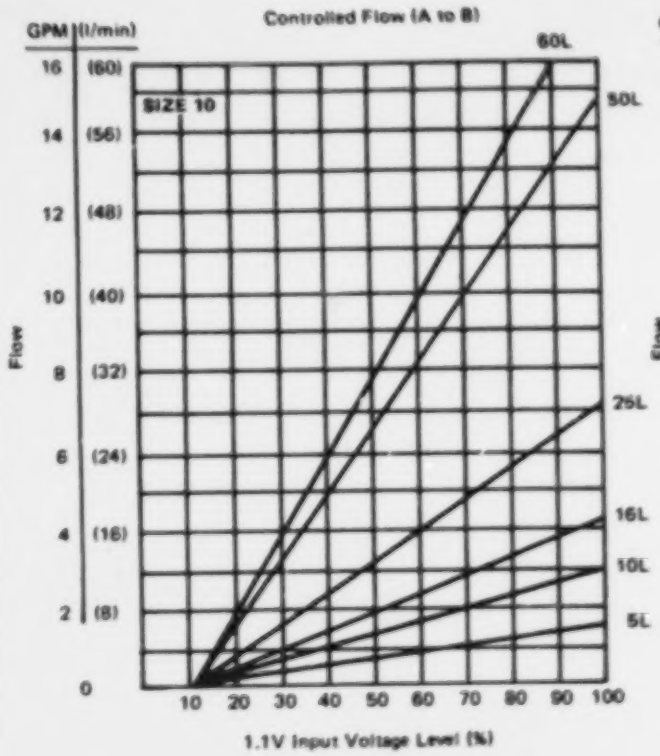
Input Step (%)	Total Elapsed Time (ms) from signal start to full required flow		Total Elapsed Time (ms) from signal start to minimum required flow	
	Size 10	Size 16	Size 10	Size 16
0 – 100	100	110	80	110
10 – 90	90	100	85	100
25 – 75	85	95	80	95

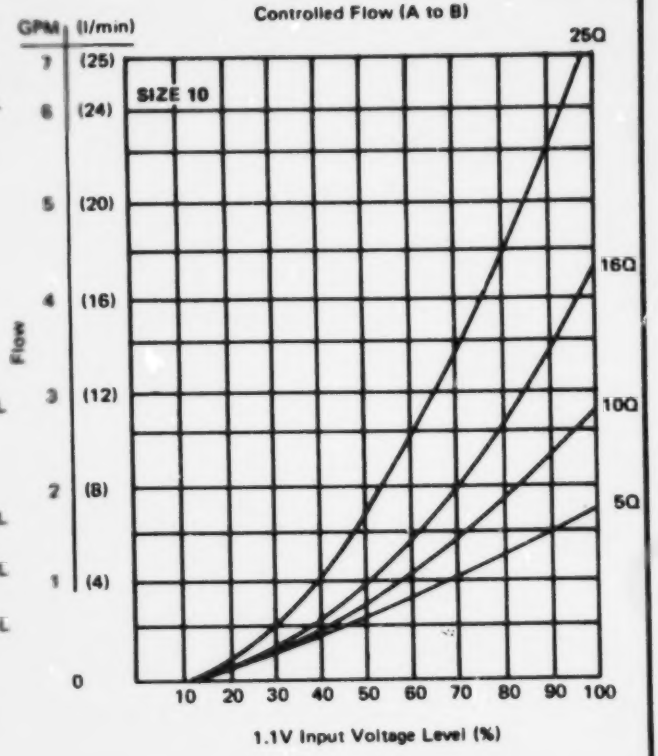


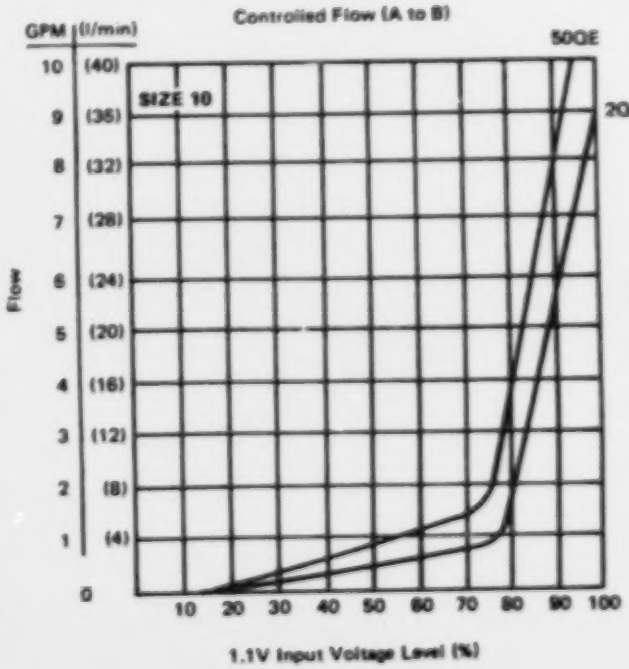


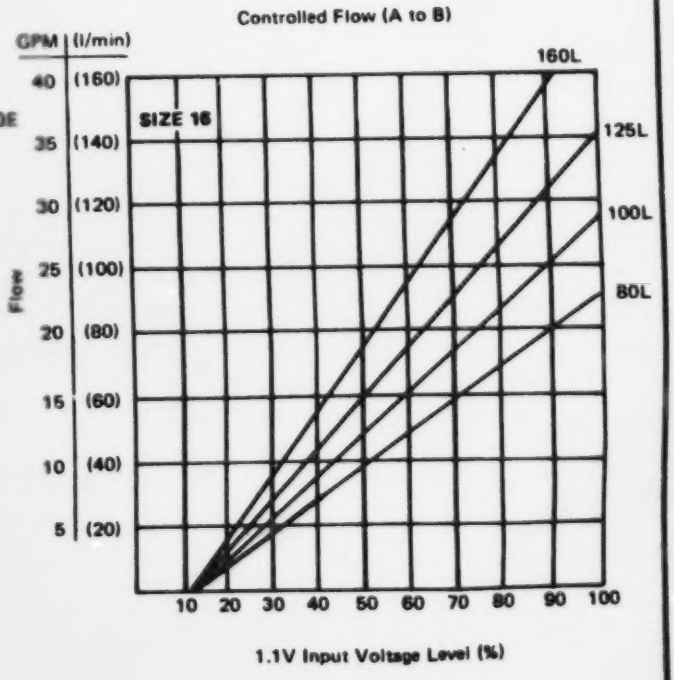
OPERATING CURVES: 2 WAY PROPORTIONAL FLOW CONTROL VALVE Measured at v = 172 SSU and t = 122°F (36cSt, t = 50°C)

RA 29190





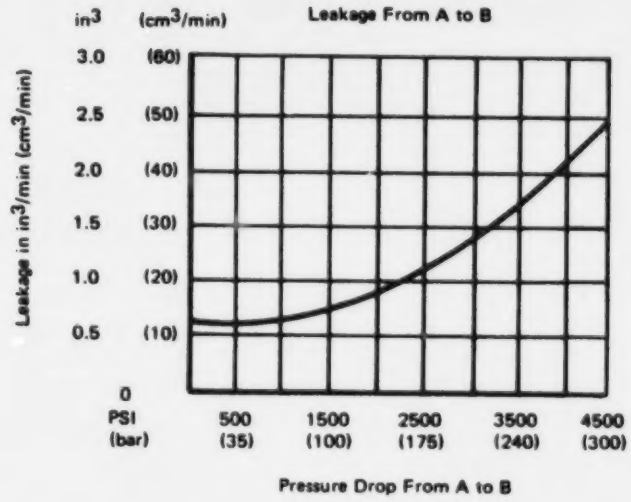




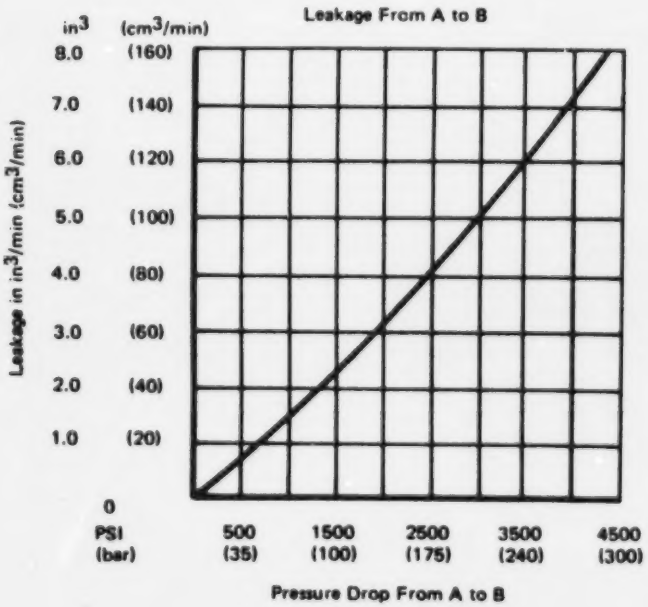
OPERATING CURVES: 2 WAY PROPORTIONAL FLOW CONTROL VALVE Measured at v = 172 SSU and t = 122°F (36cSt, t = 50°C)

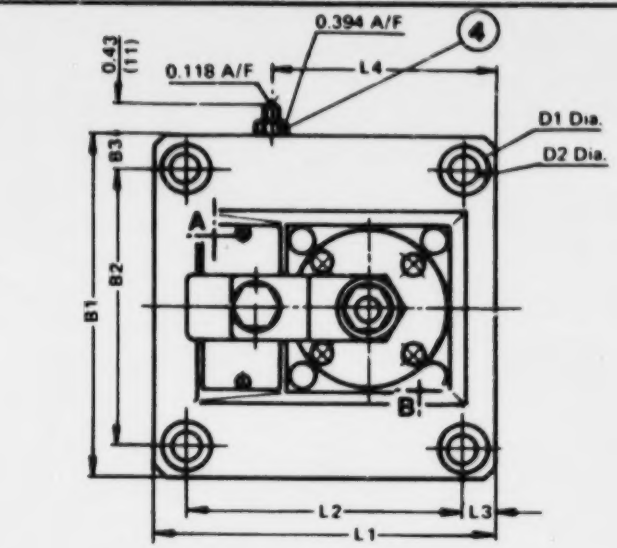
RA 29180

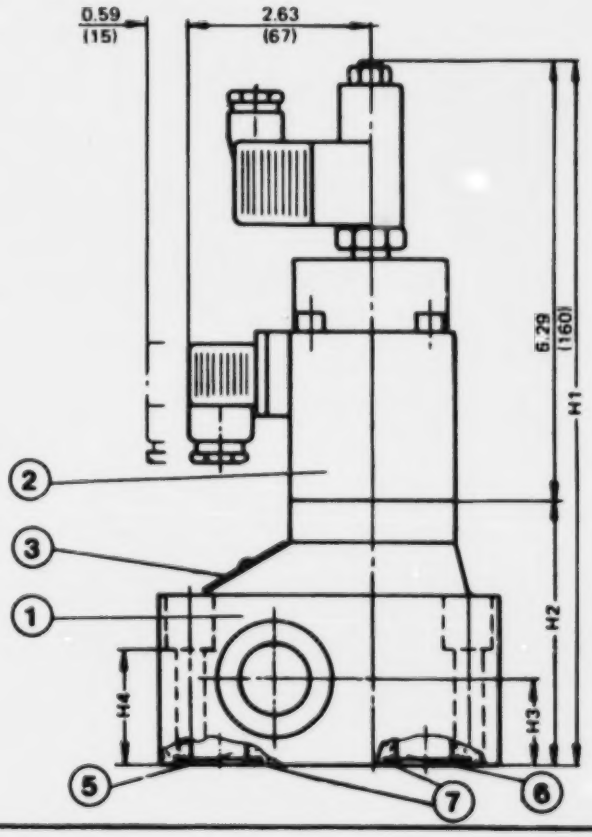
Size 10



Size 16







1 Housing

2 Proportional Solenoid with Inductive Positional Transducer

3 Nameplate

4 Stroke Limiter for Pressure Compensator

5 Inlet A

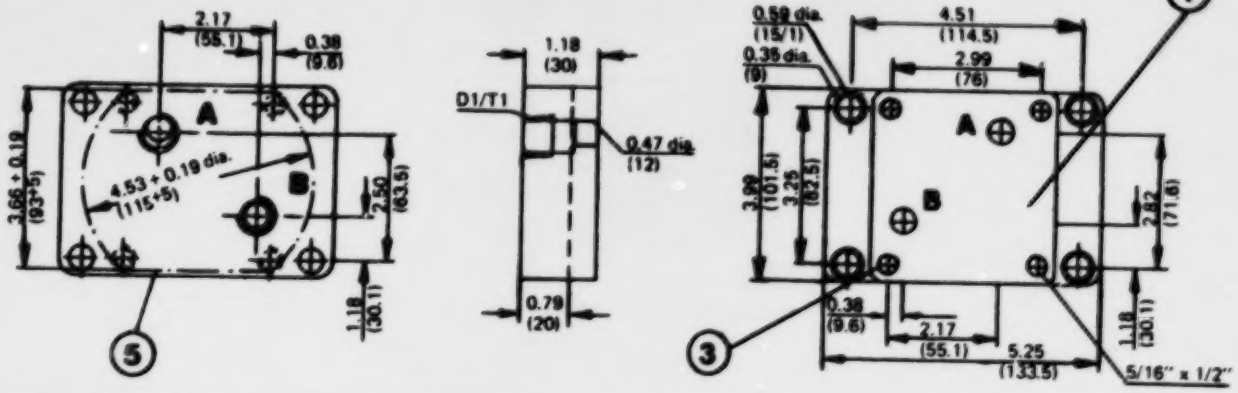
6 Outlet B

7 O-ring 18.66 x 3.53 (Size 10)
O-ring 26.58 x 3.53 (Size 16)

VALVE SIZE	B1	B2	B3	D1	D2	H1	H2	H3	H4	L1	L2	L3	L4
10	3.74 (95)	2.99 (76)	0.37 (9.5)	0.59 (15)	0.35 (9)	9.64 (245)	3.34 (85)	1.49 (38)	1.88 (48)	4.03 (102.5)	3.24 (82.5)	0.39 (10)	2.69 (68.5)
16	4.86 (123.5)	3.99 (101.5)	0.43 (11)	0.70 (18)	0.43 (11)	10.06 (255.5)	3.75 (95.5)	1.22 (31)	2.00 (51)	4.86 (123.5)	3.99 (101.5)	0.43 (11)	3.20 (81.5)

G279/5
G280/5

1/2" NPT Part No. 424435
3/4" NPT Part No. 424439

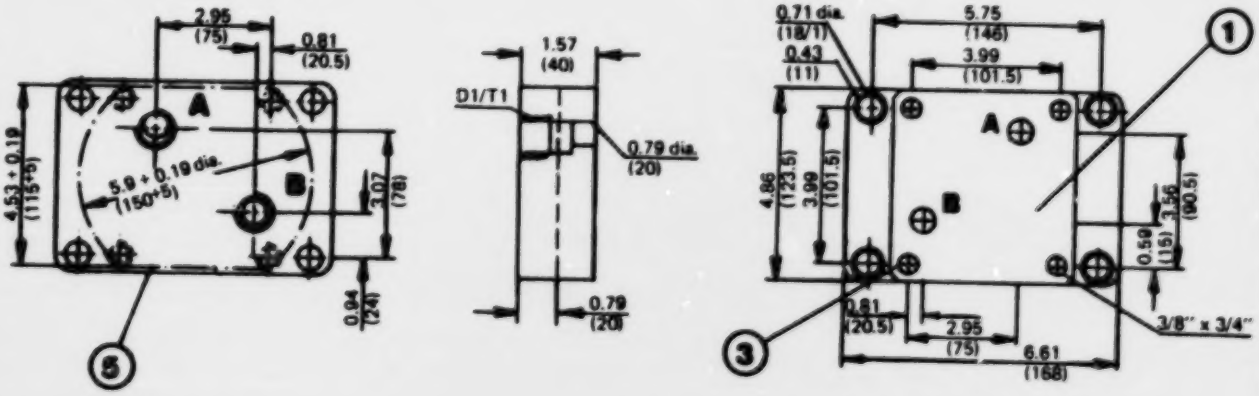


SUBPLATE	WEIGHT	D1 (NPT)	T1	TORQUE
Size 10	5 lbs (2.3 kg)	1/2" 3/4"	0.59 (15) 0.66 (17)	25.8 lb- ft (35 Nm)

Bolt Kit (4) 5/16–18 x 2" SHCS
Part No. 833373

G281/5
G282/5

1" NPT Part No. 424441
1-1/4" NPT Part No. 424443



SUBPLATE	WEIGHT	D1 (NPT)	T1	TORQUE
Size 16	8.8 lbs (4 kg)	1" 1-1/4"	0.74 (19) 0.82 (21)	51.6 lb-ft (70 Nm)

Bolt Kit (4) 3/8–16 x 3" SHCS
Part No. 833380

1 Valve Mounting Face

3 Valve Mounting Holes

5 Front Panel Cut-out

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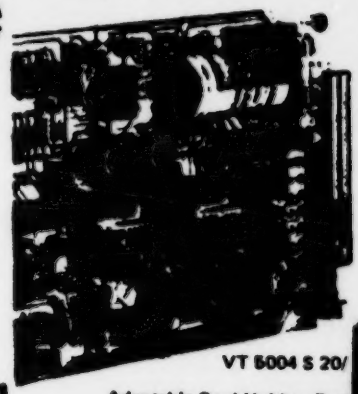
Electronics

Electrical Amplifier VT5001/5002/5003/5004 Series 20

For The Control Of Proportional Directional, Pressure & Flow Control Valves With Electrical Feedback

Amplifiers Type VT-5001/5002/5003/5004 are used for the control of proportional directional, pressure control and flow control valves with electrical feedback.

● Refer to RA 29945



VT 5004 S 20/

Adaptable Card Holders For: VT-3002, refer to RA 29916

VT-5001 for 2 position proportional directional valves Size 6 (WRE 6...A...)
VT-5002 for 2 position proportional directional valves Size 10 (4 WRE 10...A...)
VT-5003 for proportional pressure control valves (DBETR-10)
VT-5004 for proportional flow control valves 2 FRE $\frac{10}{16}$ - 40/...

The unit consists of:

- Filter Circuit
- Voltage Stabilization
- Pulse Width Modulated Output Stage
- Central Function Generator
- Oscillator and Demodulator for Inductive Feedback
- P-I-D Regulator
- Ramp Generator
- Cable Break Detection with LED Indicator

Ordering Code

VT – 50 ___ S 20 / *

CONTROL APPLICATION
Proportional Amplifier For:
- 01 = Prop. dir. valves size 6 (4 WRE 6...A...)
- 02 = Prop. dir. valves size 10 (4 WRE 10...A...)
- 03 = Prop. pressure valves, size 10 (DBETR-10)
- 04 = Prop. flow control valves, sizes 10 & 16 (2FRE $\frac{10}{16}$-40...)
- 10 = Prop. flow control valves, size 6 (2FRE 6B-10/...)

CONNECTOR CONFIGURATION
- S = 32 pole plug-in card (DIN 41612) (for installation in Euro card magazine)

DESIGN SERIES
- 20 = Design series 20

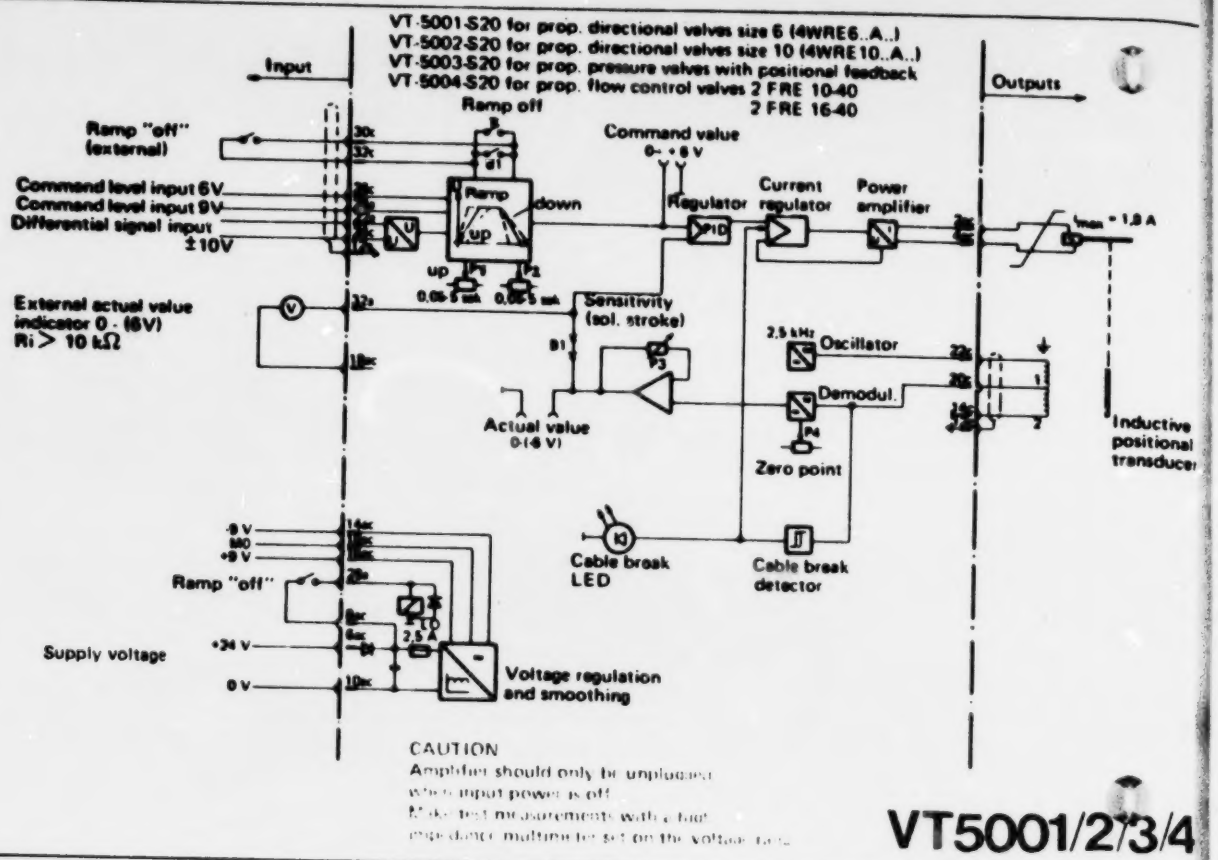
Further Details In Clear Text

Technical Data

Weight	0.88 lbs (0.40 kg)
Supply Voltage Full Bridge Rectifier	24V DC ± 10%
Power Requirement	50 watts
Fuse	2.5 amp
Reference Voltage (Internal)	± 9V
Minimum Load Resistance for Reference Voltage	500 ohms
Maximum Output Current (Imax) Solenoid A	2.2 A
Ambient Temperature Range	32 to 118°F (0 to 45°C)
Oscillator Frequency	2.5 kHz
Space Requirement	8 divisions 1.57" (40 mm)

For applications outside the above parameters, please consult Rexroth Engineering.

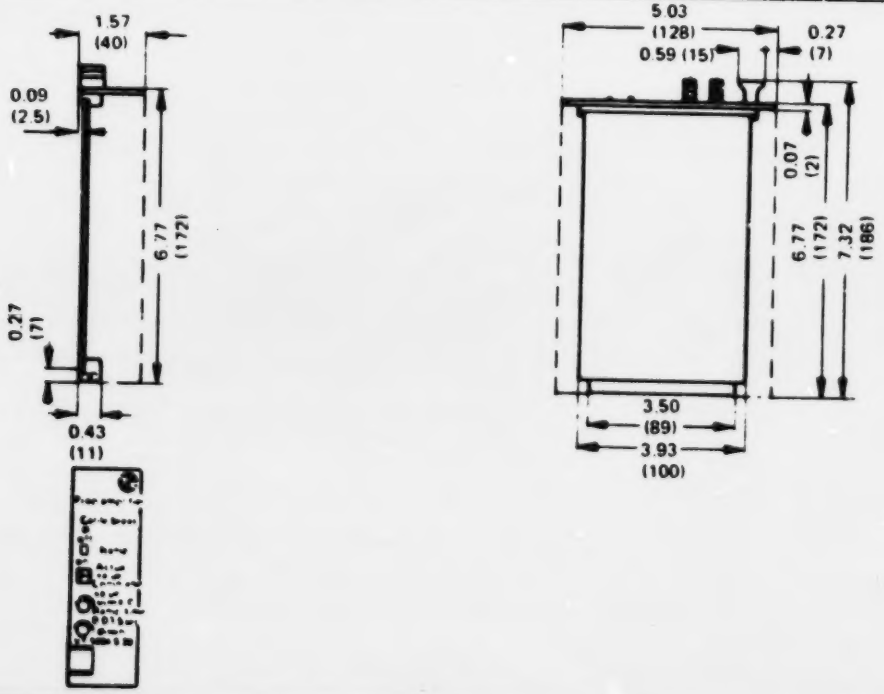
Terminal Connections



VT5001/2/3/4

Unit Dimensions

Dimensions: Inches (mm)



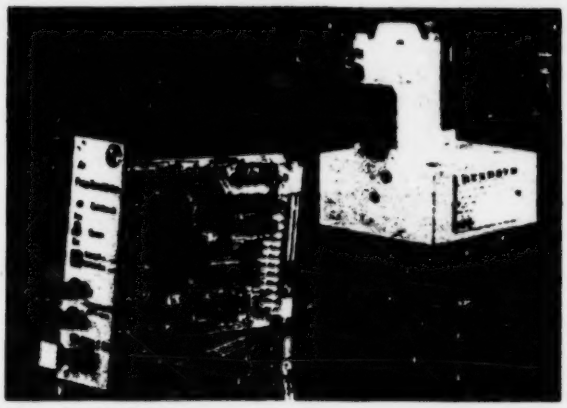
MANNESMANN REXROTH

2-Way Proportional Cartridge Valve Type FE..C, Series 10

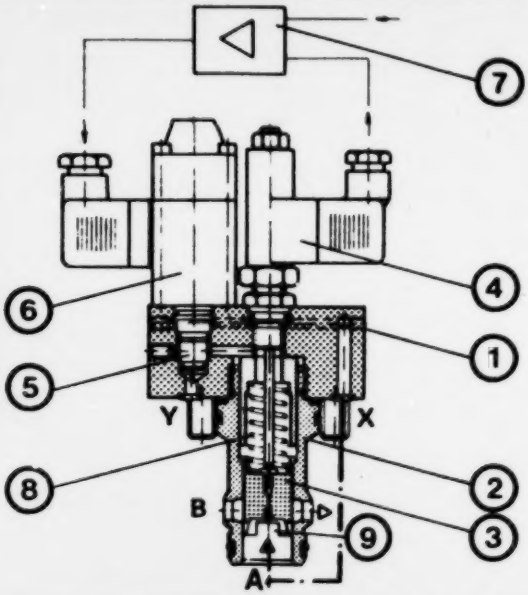
Sizes 16 ... 63	... 1800 L/min	... 315 bar

RE 29 203/11.83

Replaces: 29203/8.81 29206



Type FE 25 C 10/L...



- electrically variable single edge throttle valve
- cartridge valve insert to DIN 24342
- the stroke of the main spool is proportional to the electrical input signal (signal voltage)
- Compensation for induced errors by closed circuit positional control with electrical position feedback
- high dynamic characteristics, giving minimum control times
- may be applied with a pressure compensator as a full flow control valve, predominantly in plastics machinery and presses, etc.
- automatic closing should the input current fail
- internal or external pilot oil supply, as required

The 2-way proportional cartridge valve is an adjustable orifice, the opening stroke of which is preset by means of an electronic input signal.
The orifice is supplied as a unit ready to install, to dimensions laid out in DIN 24342 . In the cover (1) is the sleeve (2) with the main spool (3) and also the positional transducer (4) and the pilot control (5), together with the proportional solenoid (6).
The direction of flow is from A to B. The pilot oil connection X is connected to port A. The pilot oil drain Y should be led back to tank at minimum pressure.
A comparison between the external input signal and the actual value signal (feedback from the positional transducer) is made within the amplifier (7). The current to the proportional solenoid (6) is then altered to correspond to the differential value. The proportional solenoid (6) and the pilot control (5) convert the electrical positional signal into movement of the pilot control (2 edge control). The pressure in the spring chamber (8) is then so adjusted that the spring-loaded main spool (3) moves into a position corresponding to the input signal value.
Should the current fail, or the cable break, the orifice closes automatically (safety control).
The components of the positional control circuit are so arranged that the input value and the stroke of the spool (3) are directly proportional to each other. It follows that, for a constant pressure difference across the orifice, the volumetric flow from A to B is only dependent on the spool itself and the window geometry (9).
Direct proportionality is achieved between input value and output flow, with linear opening characteristics (FE..C10/L). Model FE..C10/Q is arranged according to quadratic opening laws, giving a quadratic relationship between input value and throughflow.

Ordering Code

FE		C	10 /		•

Size 16 = 16 | Size 25 = 25 | Size 32 = 32 | Size 40 = 40 | Size 50 = 50 | Size 63 = 63

Cartridge element = C

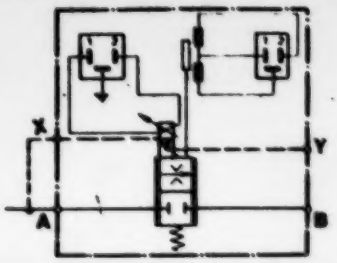
Series 10 = 10
(10 to 19 ≙ installation and connection dimensions remain unchanged)

Flow characteristic linear = L | progressive = Q

mineral oils to DIN 51524 and 51525 = M | emulsion = E
phosphate-ester = V | water-glycol = W

Schematic Diagram

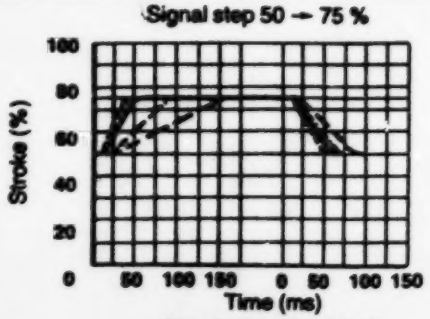
Schematic Diagram with Electrical Connections



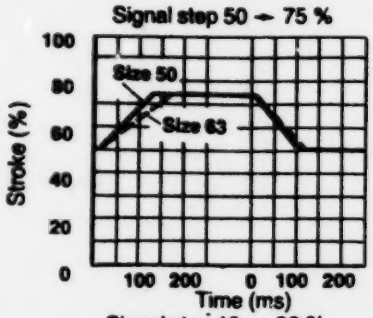
A input port
B output port
X pilot oil input port
Y pilot oil drain port

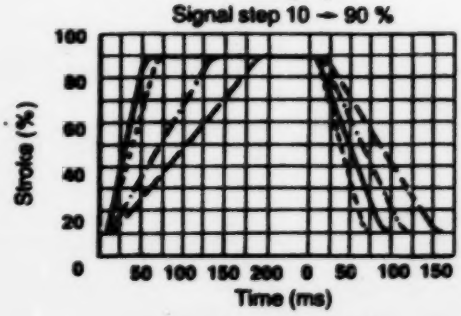
Direction of Flow: A to B

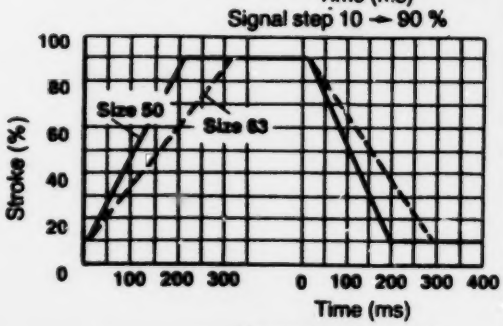
Valve Response with Stepped Electrical Input Signal

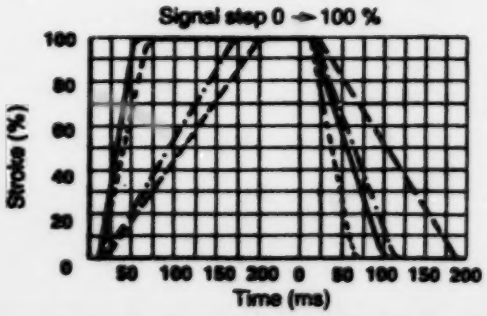


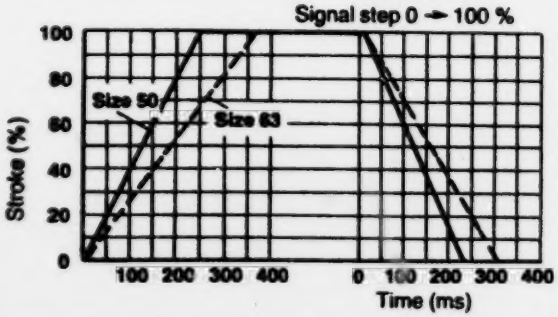
Size 16
Size 25
Size 32
Size 40



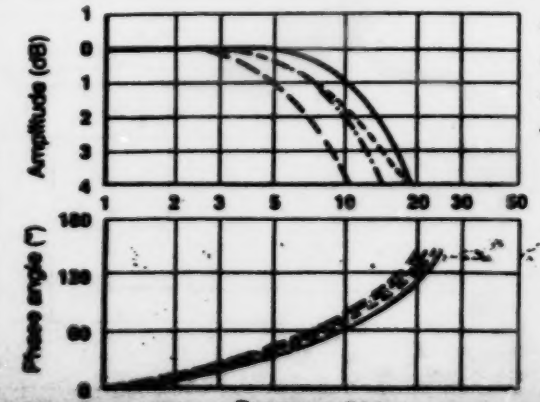




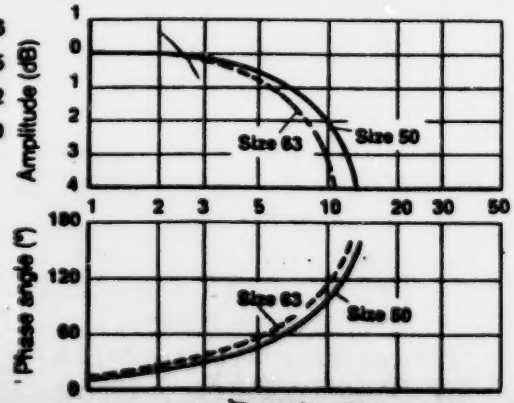




Frequency Characteristic Curves (measured at p_A = 50 bar; $p_B \approx 0$; U_{input} = 4.5 V; sine wave ampl. ΔU_{input} = 0.5 V)



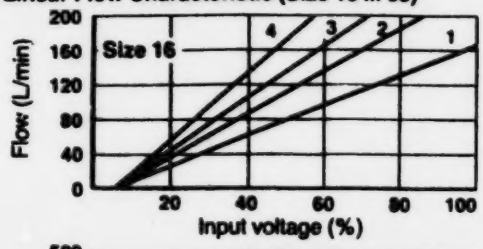
Size 16
Size 25
Size 32
Size 40



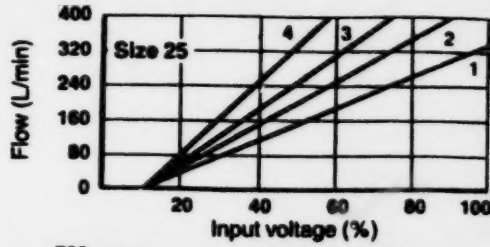
L3

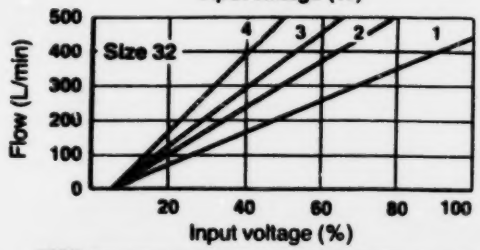
Operating Curves (measured at ν = 36 mm²/s and t = 50 °C)

I Linear Flow Characteristic (Size 16 ... 63)

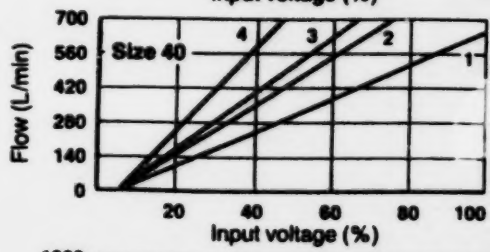


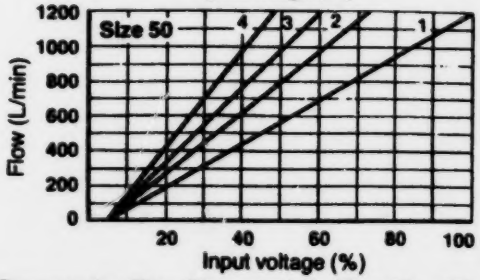
Typ FE^{16}_{25} C/10 L
1 Δp = 10 bar
2 Δp = 20 bar
3 Δp = 30 bar
4 Δp = 50 bar



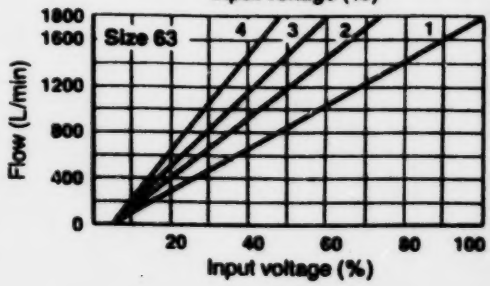


Typ FE^{32}_{40} C/10 L
1 Δp = 10 bar
2 Δp = 20 bar
3 Δp = 30 bar
4 Δp = 50 bar

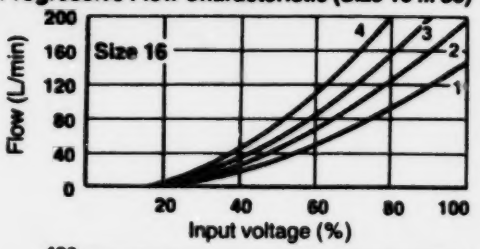




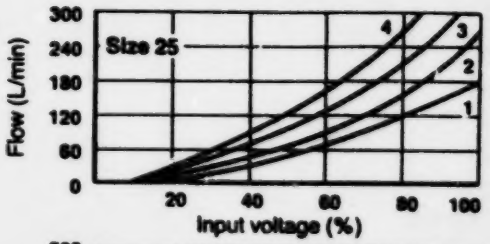
Typ FE^{50}_{63} C/10 L
1 Δp = 10 bar
2 Δp = 20 bar
3 Δp = 30 bar
4 Δp = 50 bar

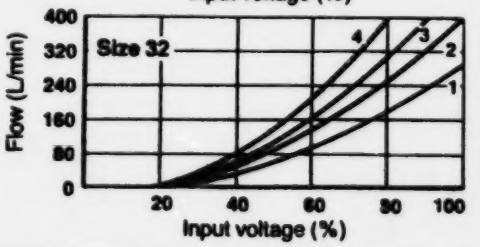


II Progressive Flow Characteristic (Size 16 ... 30)

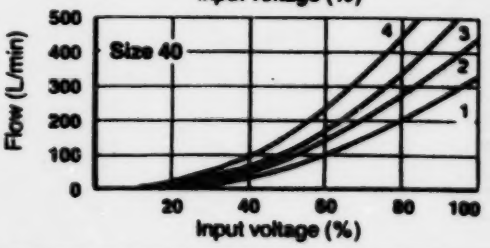


Typ FE^{16}_{25} C/10 Q
1 Δp = 10 bar
2 Δp = 20 bar
3 Δp = 30 bar
4 Δp = 50 bar





Typ FE^{32}_{40} C/10 Q
1 Δp = 10 bar
2 Δp = 20 bar
3 Δp = 30 bar
4 Δp = 50 bar



Technical Data (For applications outside the above parameters, please consult us!)

hydraulic

Operating pressure Ports A and B: ... 315 bar

Return line pressure Port Y: ... max 30 bar

Control volume for valve movement: 0 → 100 %

Size	16	25	32	40	50	63
cm³	...0,9	...1,9	...3,5	...5,7	..19,9	..35,3

Pilot oil flow at port Y for stepped from input signal:
... 2.5 L/min (Size 16 ... 40)
... 6.5 L/min (Size 50, 63)

Flow through main valve: at Δp 10 bar

Size	16	25	32	40	50	63
Mod. L	160	340	450	670	1200	1800

Filtration: ≤ 20 µm

Fluid: mineral oils to DIN 51524 and 51525 phosphate ester, emulsions, water-glycol

Fluid temperature range: –20 ... + 70 °C

Viscosity range: 2.8 ... 380 mm²/s

Hysteresis: ... 1 %

Repeatability: ... 1 %

Mounting position: optional

Weight:

Size	16	25	32	40	50	63
kg	2,3	3,1	4,0	5,9	12,0	20,0

Technical Data: electrical

Proportional Solenoid

Supply: DC

Nominal current: 680 mA (Size 16...40), 800 mA (Size 50, 63)

Coil resistance, cold at 20 °C:
24.6 Ω (Size 16...40), 19.5 Ω(Size 50, 63)

Duty: Continuous

Ambient temperature: ... + 50 °C

Coil temperature: ... + 150 °C

Electrical connection: Plug connection to DIN 43650

Insulation: IP 65 to DIN 40050

Positional Transducer

Supply voltage: 1 ... 15 V

Carrier frequency: 2 ... 5 kHz (Size 16 ... 63)

Coil resistance, cold at 20 °C: 55 Ω

Temperature: 80 °C

Electrical connection: Plug connection to DIN 43650

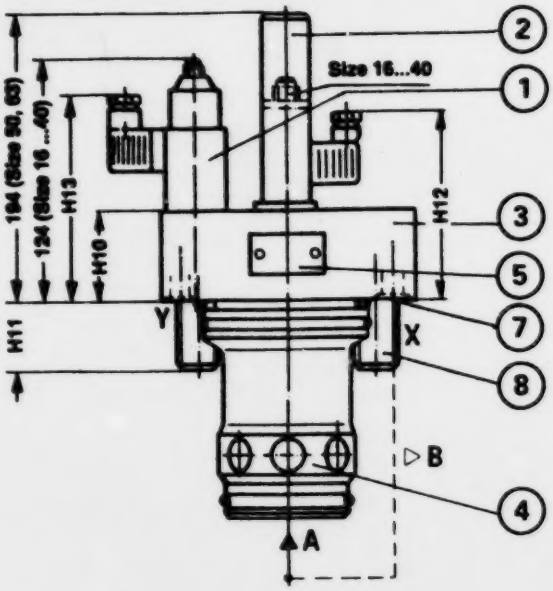
Insulation: IP 65 to DIN 40050

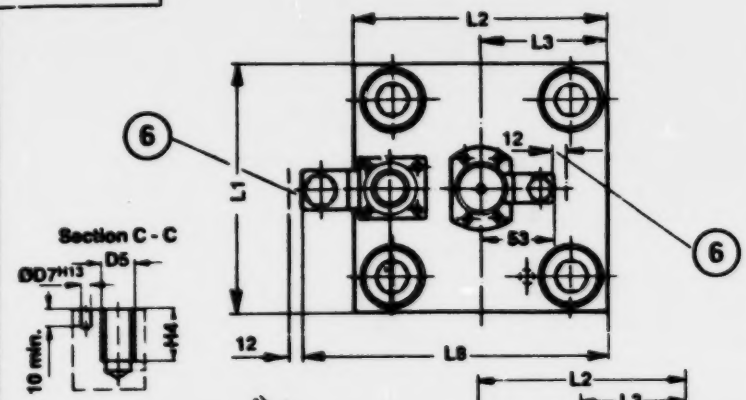
Associated amplifier: VT 5011 ... VT 5016
(dependent on valve size; see RE 29 956)

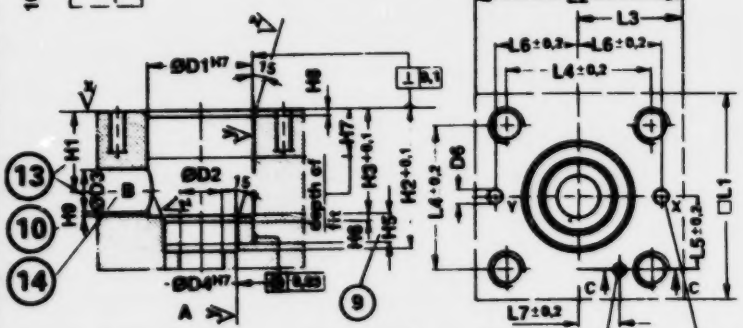
Size	16	25	32	40	50	63
ØD1	32	45	60	75	90	120
ØD2	16	25	32	40	50	63
ØD3	16	25	32	40	50	63
ØD3(*)	25	32	40	50	63	80
ØD4	25	34	45	55	68	90
ØD5	M8	M12	M16	M20	M20	M30
ØD6(*)	4	6	8	10	10	12
ØD7	4	6	6	6	8	8
H1	34	44	52	64	72	95
H1(**)	29,5	40,5	48	59	65,5	86,5
H2	56	72	85	105	122	155
H3	43	58	70	87	100	130
H4	20	25	35	45	45	65
H5	11	12	13	15	17	20
H6	2	2,5	2,5	3	3	4
H7	20	30	30	30	35	40
H8	2	2,5	2,5	3	4	4
$H8_{min}$	0,5	1	1,5	2,5	2,5	3
H10	40	40	40	40	65	65
H11	14,5	18,5	22	31	37	50
H12	106	106	106	106	132	132
H13	105	105	105	105	140	140
L1	65	85	100	125	140	180
L2	83	93	100	125	140	180
L3	32,5	42,5	50	62,5	70	90
L4	46	58	70	85	100	125
L5	23	29	35	42,5	50	62,5
L6	25	33	41	50	58	75
L7	10,5	16	17	23	30	38
L8	121	131	139	159	173	212

(*) max. M6; (**) bei ØD3 max.

Unit Dimensions (dimensions in mm)







$\sqrt[x]{} = \sqrt{R\ max\ 4}$; $\sqrt[y]{} = \sqrt{R\ max\ 8}$; $\sqrt[z]{} = \sqrt{R_z 10}$

1 Proportional solenoid
2 Positional transducer
3 Cover
4 Sleeve
5 Nameplate
6 Clearance to remove plug
7 O-ring
8 Socket head cap screws
9 Tolerance held to this depth
10 Check dimension
11 Drilling for locating pin
12 Connect port X to port A
13 For other diameters of port B as given in the dimension table, the centre distance of the hole must be calculated from the cover mounting face
14 Port B may be placed at any point around the central axis of port A, but clearance must always be allowed for the fixing screw holes

ights reserved –
ject to revision

Electronics

Electrical Amplifier VT5011

Series 20

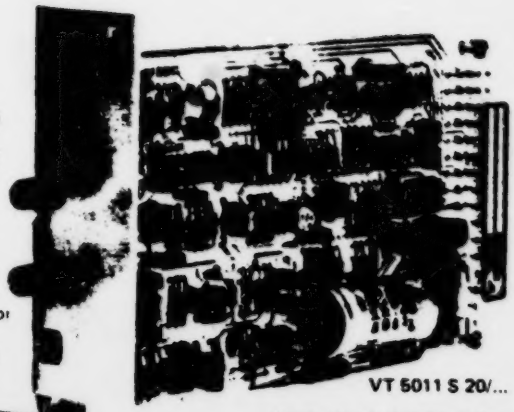
For The Control Of Electrically Variable Throttle Valves Type FE

●Refer to RA 29956

Amplifier Type VT-5011 serves to electrically control variable throttle valves Type FE, Sizes 16, 25, 32 and 40

The unit consists of:

- Filter Circuit
- Voltage Stabilization
- 1 Switched Power Amplifier
- Pulse Width Modulator
- Oscillator and Demodulator for Inductive Positional Feedback
- P-I-D Regulator
- Ramp Generator
- Function Generator
- Differential Signal Input



VT 5011 S 20/...

Adaptable Card Holders For:
VT 3002, refer to RA 29916

Ordering Code

VT–5011 S 20/*

CONNECTOR CONFIGURATION
S = 32 pole plug-in card (DIN 41612)
(for installation in Euro card magazine)

DESIGN SERIES
20 = Design series 20

Further Details In Clear Text

Technical Data

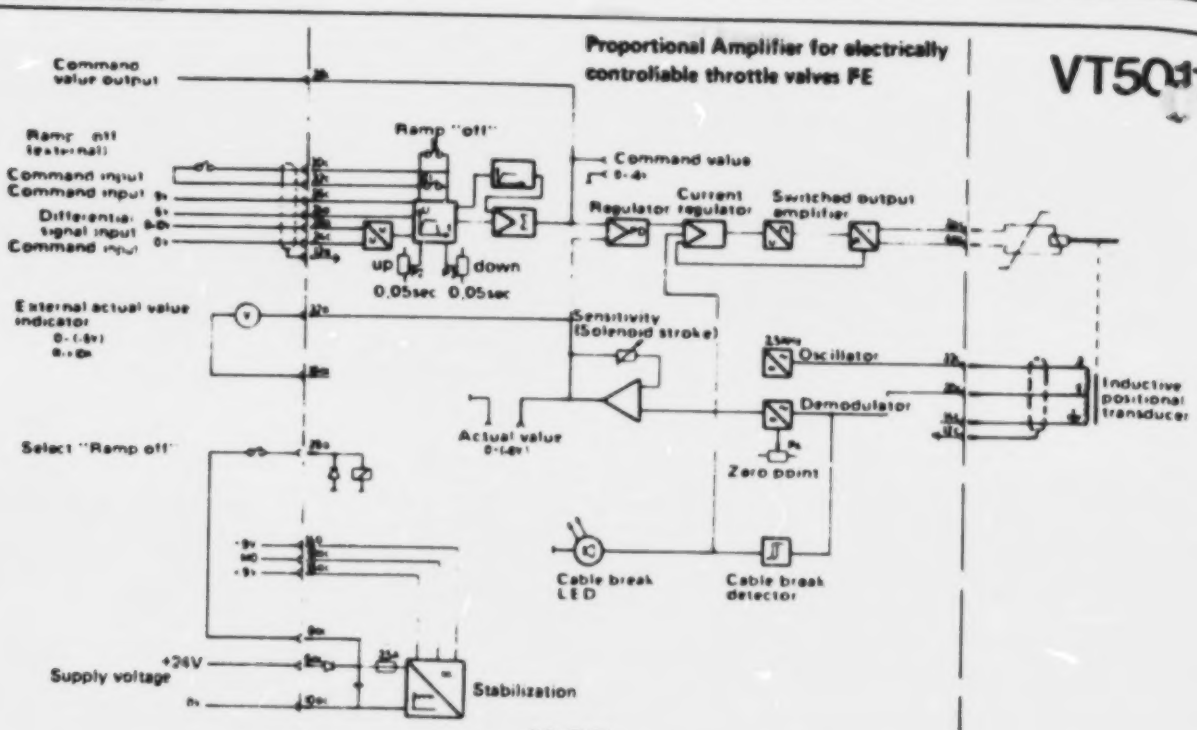
Weight	0.88 lbs (0.40 kg)
Supply Voltage	24V DC ± 10%
Power Requirement	30 watts
Fuse	1.2 amp
Reference Voltage (Internal)	± 9V
Minimum Load Resistance for Reference Voltage	500 ohms
Maximum Output Current (Imax) Solenoid A	700 mA
Ambient Temperature Range	32 to 122°F (0 to 50°C)
Oscillator Frequency	2.5 kHz
Space Requirement	8 divisions 1.57" (40 mm)

For applications outside the above parameters, please consult Rexroth Engineering

Terminal Connections

Proportional Amplifier for electrically controllable throttle valves FE

VT5011



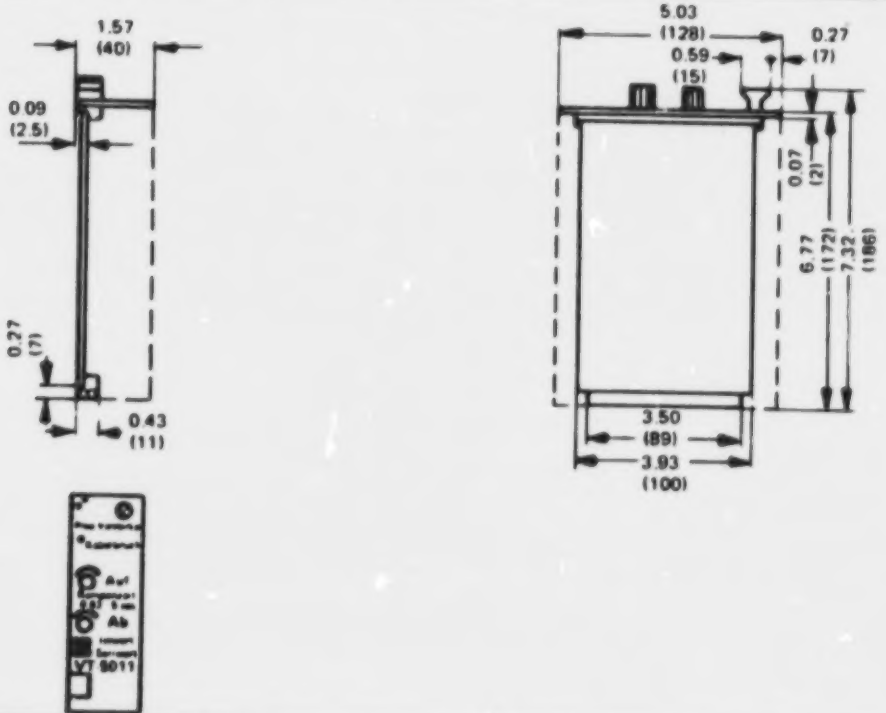
CAUTION

Amplifier should only be unplugged when input power is off.

Make all measurements with a high impedance multimeter set on the voltage range.

Unit Dimensions

Dimensions: Inches (mm)



MANNESMANN REXROTH	Proportional Directional Valve **Type 4 WRD 32, 4 WRDE 32/Series 30 with Feedback of Main Spool Position**			RE 29 104/4.83
	Size 32	... 350 bar	... 1600 L/min	

- pilot operated 3-stage proportional directional valve
- 1 valve for regulation of volume and direction of oil flow
- special models for pressure, flow, speed and position regulation
- low pressure drop across the control lands
- 2-stage servo valve pilot operation
- main spool with electrical feedback
- integrated control electronics (WRDE)
- valve and matched control electronics (closed loop) from one source
- subplate mounting
- connection dimensions to DIN 24340, Form A

K3708/01

Type 4 WRD 32...-30/

K3707/11

Type 4 WRDE 32...-30/

Description of Function, Section

Pilot Control (2-stage)

1st Stage 4DS 1EO-2-10..

The 1st stage is an electrically operated servo pressure valve which operates on the principle of a jet/flapper plate valve.
The electrical control current brings the solenoid system out of balance and thus deflects the flapper plate (6) between the two regulating jets (7).
This change in the flapper plate position causes an alteration in the jet opening, and thus a variable pressure drop to move the control spool.

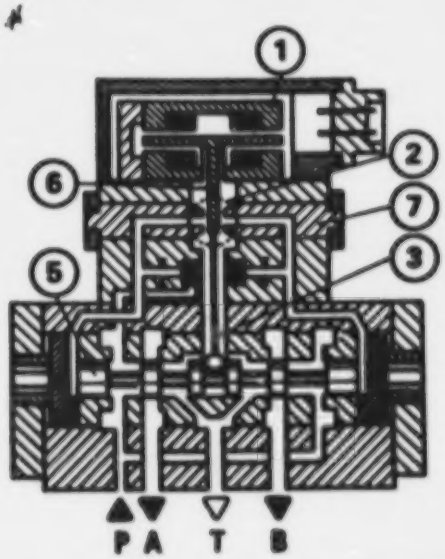
2nd Stage, Mechanical Feedback

Q = proportional to z_t (mA)

The control spool (5) is connected to the control motor (1) of the first stage virtually free of play by means of the mechanical feedback (3).
The type of feedback used here compares the torque of the control motor (1) with the torque on the feedback spring (3).

This means that, when the torques are unequal, caused by a change in the electrical input signal, the flapper plate (6) is moved from centre position between the two regulating jets. This creates a pressure differential which affects both ends of the control spool. The effect of the pressure differential is to cause the control spool (5) to change its position. This change in position continues until the torques are in equilibrium again and the pressure differential is zero.
The stroke of the control spool (5) and thus the flow of the 4-way servo valve is proportional to the electrical input signal.

VT10
EWALD
-12



Valves type 4 WRD/4 WRDE are 3-stage proportional directional valves.

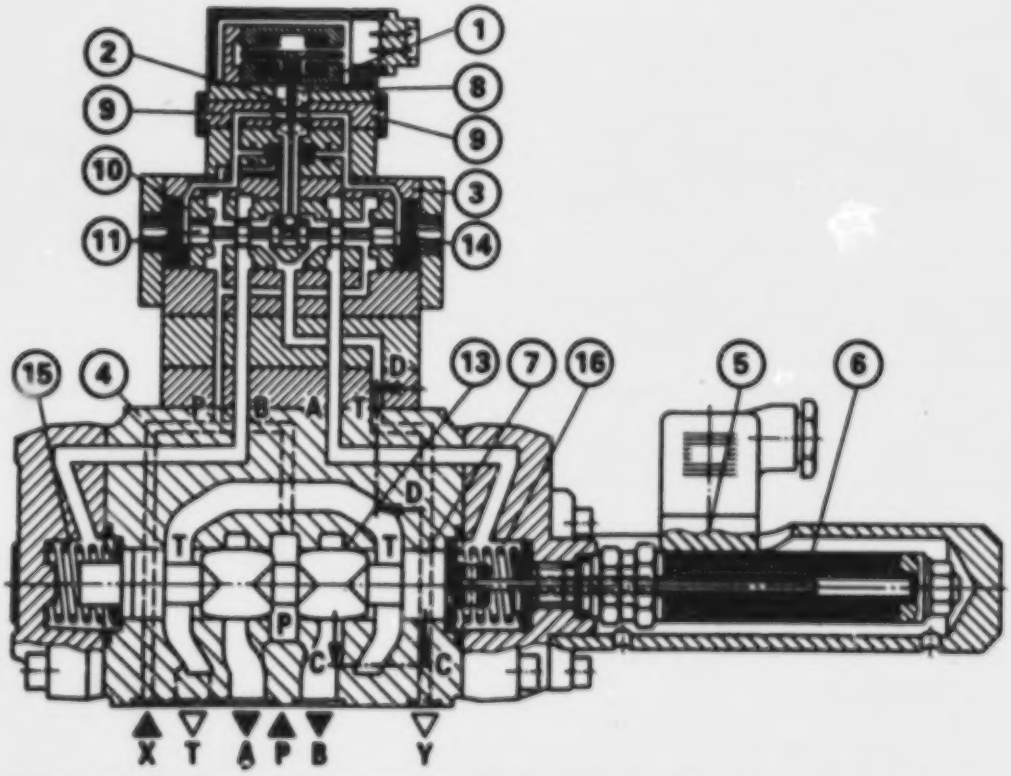
They are used to control volume and direction of an oil flow, and may also be used in closed circuits for various regulating functions.

They consist basically of:

- the 1st stage with its torque motor (1) and hydraulic amplifier (2) designed as a jet/flapper plate valve.
- the 2nd stage (3) operating as a pilot flow amplifier for the 3rd stage (4).
- the 3rd stage (4), which is used to control the main oil flow.
- an inductive positional transducer (5), the armature of which is firmly attached to the control spool (7) of the 3rd stage.

The control spool (7) is coupled to its own electronic circuit via the inductive positional transducer (5).
A differential voltage is generated at the comparator of the regulating amplifier, either by a change of position of the control spool (7) or an alteration in the input signal.

Any variation between the input and the output signals is evaluated, amplified and utilised as the regulating signal to the first stage of the valve. This signal operates the flapper plate (8) between the two regulating jets (9), thus generating a pressure differential between the two pilot control chambers (10 and 14). The pilot spool (11) is offset, and feeds the relevant volume of oil to the control chambers (15 or 16). The control spool (7), together with the armature (6) of the inductive positional transducer (5) is moved sufficiently to make the input and output signals equal once more. In the regulated condition, the pressure in the two control chambers (15 and 16) are almost equal, and the control spool is held in this regulated position.
For regulating a flow, the relative position of the control spool (7) to the control lands (13) gives a specific valve opening area, which is proportional to the spool stroke and therefore to the input signal value, and also to the throughflow.
Valve frequency response is optimised in the electronic control by the electrical amplification.
In valve type 4 WRDE, the control electronics are built into the valve. By exactly matching the valves to the electronics, random variations within the device are kept to a minimum.



Special features of the Valve

Valves of this type have connection dimensions for the main valve (3rd stage) to DIN 24340.

The first and second stages of the valve are from the Rexroth modular servo valve range.

The third stage is part of the modular proportional valve system. The filter element in the first stage can be changed without difficulty. Due to the encapsulated design of the filter, no dirt particles can enter the pilot control system.

Easy access to the null point adjustment.

The pilot control, i.e. the first and second stages, or the first or second alone, is easily replaced.

Type 4 WRD(E) 32..30/...

This model has external pilot supply from a separate control line.
Pilot drain is fed separately to tank via Y (external), not into the T line of the main valve.

Item 12: Plug M6 DIN 906-8.8, 3 A/F

Type 4 WRD(E) 32..30/..E..

This model has internal pilot supply from the P line of the main valve.
Pilot drain is fed separately to tank via Y (external) not into the T line of the main valve.
Port "X" in the subplate is closed.

Item 12: Plug M6 DIN 906-8.8, 3 A/F

Type 4 WRD(E) 32..30/..ET..

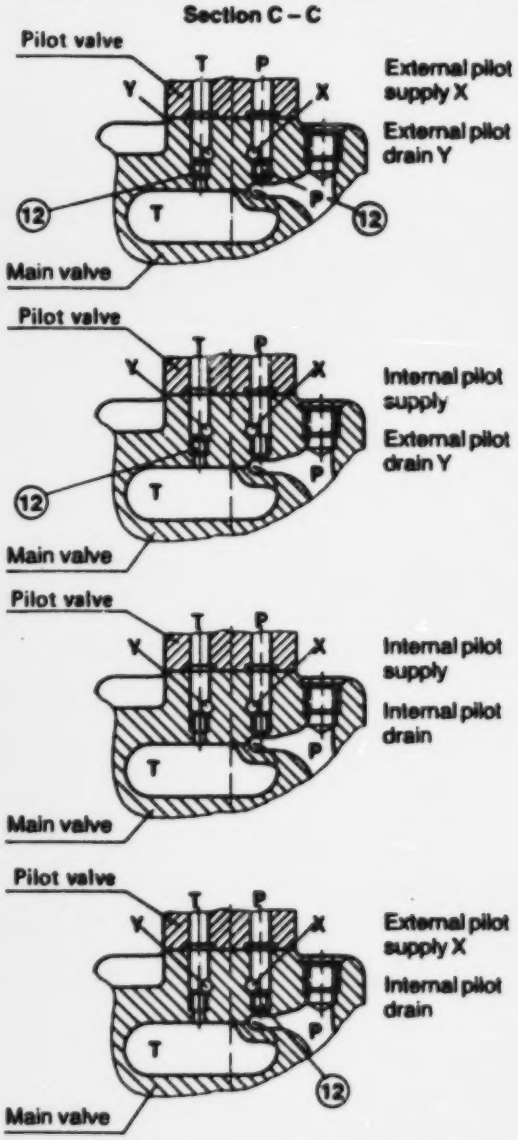
This model has interal pilot supply from the P line of the main valve.
Pilot drain is internal directly into the T line of the main valve.
Ports "X" and "Y" in the subplate are closed.

Type 4 WRD(E) 32..30/..T..

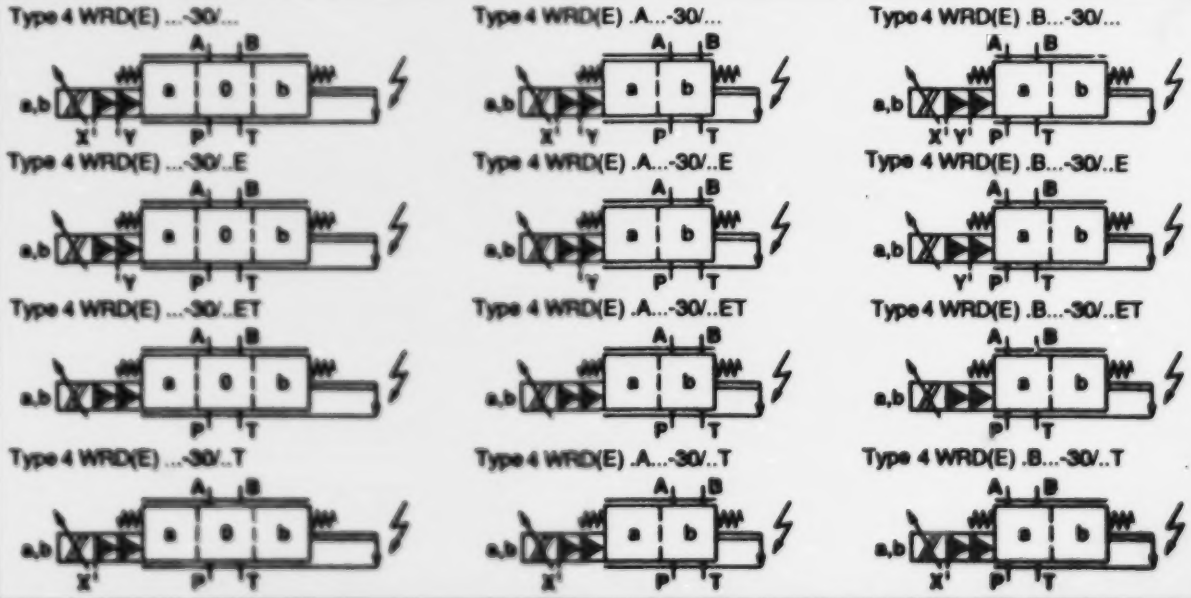
This model has external pilot supply from a separate control circuit.
Pilot drain is internal directly into the T line of the main valve.
Port "Y" in the subplate is closed.

Item 12: Plug M6 DIN 906-8.8, 3 A/F

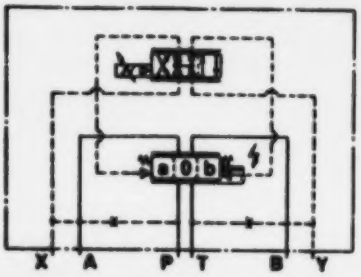
Section C – C



Valve Symbols (simplified)

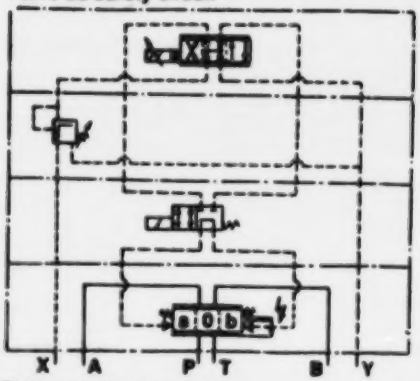


Example:
Type 4 WRD...-30/...



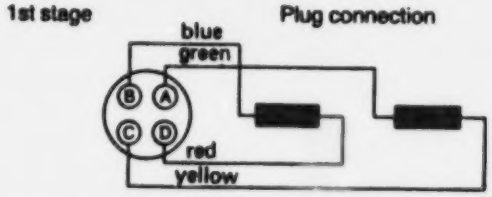
External pilot oil supply
External pilot oil drain

Example:
Type 4 WRD...-30/.. with pressure reducing valve Type ZDR 6 DP-30/.. and sandwich plate directional valve as safety circuit

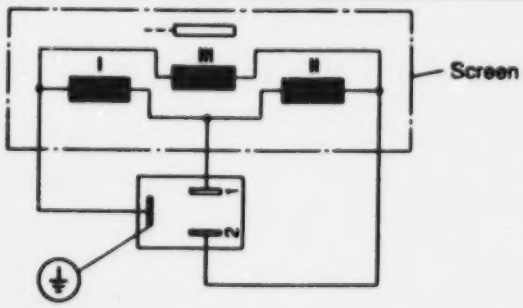


External pilot oil supply
External pilot oil drain

Electrical Connections: Type 4 WRDE 32 ...

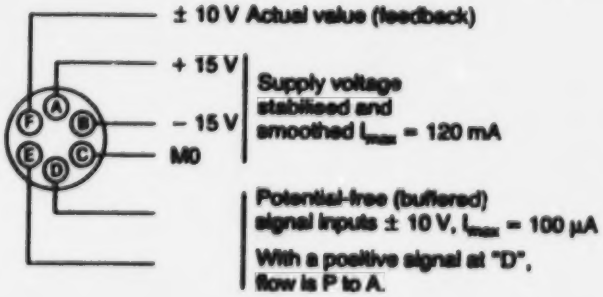


Parallel circuit: mating plug connection A connected to B and C to D (bridged)
Electrical signal from A (+) to D (−) at plug connection gives a flow direction for the 3rd stage of P to A and B to T.
Reversed signal current gives reversed operation of the 3rd stage from P to B and A to T.



If, on commissioning, the valve spool moves immediately to one end position, electrical connections 1 and 2 must be reversed.

Electrical Connections: Type 4 WRD 32 ...



L1

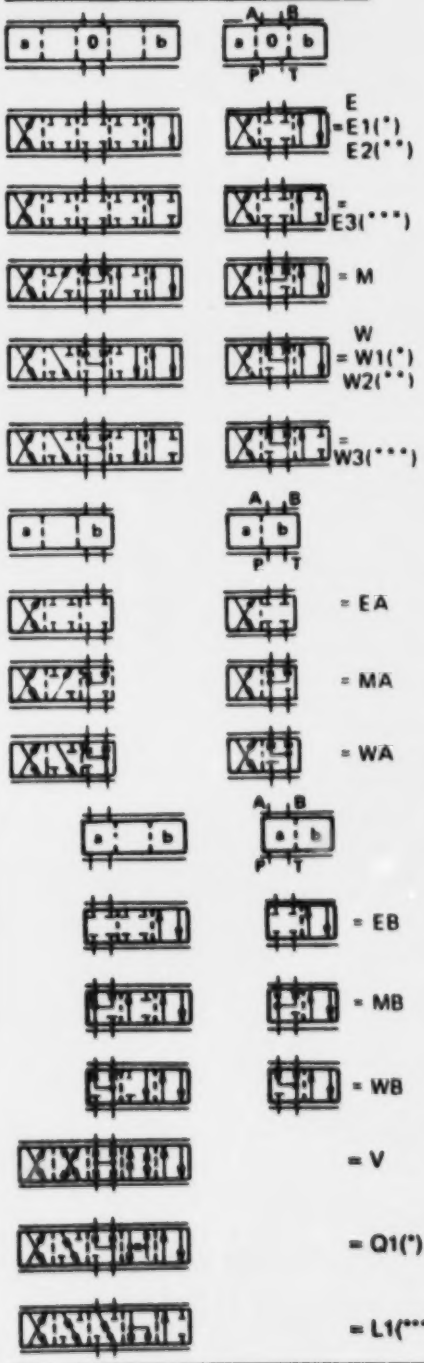
Ordering code

4 WR	D		32		– 30 / 10 L	2								*

Three-stage valve, electro-hydraulic operation

Without integrated electronics = no code

With integrated electronics (final stage) = E



Further details in clear text

M = Mineral oils to DIN 51 524 and 51 525
V = Phosphate-ester

No code = without sandwich plate directional valve

WG 011 = with sandwich plate directional valve, size 6 12 V DC, Z4 plug

WG 021 = with sandwich plate directional valve, size 6 24 V DC, Z4 plug

No code = without pressure reducing valve

D2 = with pressure reducing valve ZDR 6 DP2-30/150 YM

Z8 (WRD only) = socket with mating plug MS 3106, size 14 S
Z9 (WRDE only) = socket with mating plug MS 3106, size 14 S

K8 (WRD only) = socket without mating plug
K9 (WRDE only) = socket without mating plug

No code = external pilot supply, external pilot drain
E = internal pilot supply, external pilot drain
ET = internal pilot supply, internal pilot drain
T = external pilot supply, internal pilot drain

No code = no special protection
J = seawater resistant

2 = coil no. 2 (30 mA/40 Ohms per coil)

10 L = servo pilot valve size 10

30 = series 30
(30 to 39 ≙ installation and connection dimensions remain unchanged)

360 = 360 L/min nominal flow at 10 bar pressure drop across valve
520 = 520 L/min nominal flow at 10 bar pressure drop across valve
E1, E2, E3, W1, W2, W3 only for 520 L/min nomal flow

(*) For spool types E1, W1 and Q1:
$P \rightarrow A\ Q = 520$ L/min / $B \rightarrow T = \frac{Q}{2}$
$P \rightarrow B = \frac{Q}{2}$ / $A \rightarrow T\ Q = 520$ L/min

(**) For spool types E2 and W2:
$P \rightarrow A = \frac{Q}{2}$ / $B \rightarrow T\ Q = 520$ L/min
$P \rightarrow B\ Q = 520$ L/min / $A \rightarrow T = \frac{Q}{2}$

(***) For spool types E3 and W3:
$P \rightarrow A\ Q = 520$ L/min / $B \rightarrow T$ blocked
$P \rightarrow B$ / $A \rightarrow T\ Q = 520$ L/min
(For regenerative control, connect full bore of cylinder to port A)

(****) For spool types L1:
$P \rightarrow A\ Q = 520$ L/min / $B \rightarrow T$ blocked
$P \rightarrow B = \frac{Q}{2}$ $A \rightarrow T\ Q = 520$ L/min

Technical Data (for applications outside these parameters, please consult us!)

Hydraulic

Operating pressure:

- **Pilot valve**
  - external pilot oil supply up to 150 bar
    internal pilot oil supply up to 150 bar
    (above 150 bar, we recommend that a pressure reducing valve type ZDR 6 Dp 2-30/150 YM be mounted between the pilot valve and the main valve)
- Main valve up to 350 bar

Return line pressure:
Port T (external pilot oil drain) up to 250 bar
Port T (internal pilot drain) up to 4.5 bar
Port Y up to 4.5 bar

Pilot oil volume for valve spool operation 0 – 100 %: 26.5 cm^3

Pilot oil flow at port X or port Y if stepped input signal 0 – 100 % is applied
16 L/min

Flow of main valve: up to 1600 L/min

Filtration: ≤ 20 µm (main valve)
≤ 10 µm absolute (pilot control)

Fluid: mineral oils to DIN 51524 and 51525; phosphate-ester

Fluid temperature range:
– 20 ... + 70 °C (main valve)
+ 10 ... + 90 °C (pilot control)

Viscosity range: 2.8 ... 380 mm^2/s

Hysteresis: ≤ 1 %

Repeatability: ≤ 0.5 %

Mounting position: optional

Weight: 36.1 kg (4 WRD 32)
36.2 kg (4 WRDE 32)

Electrical: 1st Stage

Coil: no. 2

Nominal current per coil: 30 mA

Resistance per coil: 40 Ohms

Inductivity: 70 mH

Insulation to DIN 40050: IP 65

Recommended dither signal:
≤ ± 10 % of nominal current, frequency 100 to 250 Hz

Electrical: Inductive Positional Transducer

Electrical measuring system: differential resistance

Regulated stroke: ± 9 mm

Linearity tolerance: 1 %

Coil resistance I R 20 – 57 Ohms
II R 20 – 57 Ohms
III R 20 – 118 Ohms

Electrical connection: plug connection to DIN 43650-BF2-PG 9

Insulation to DIN 40050: Ip 65

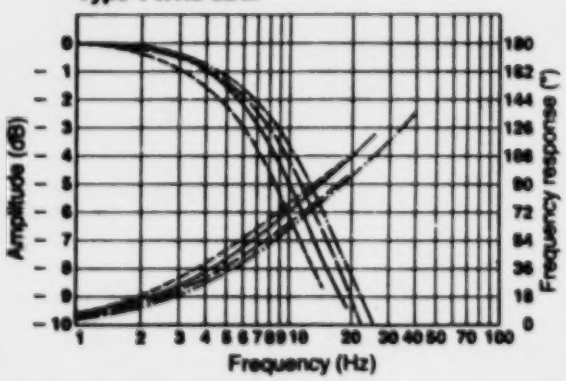
Inductivity: 3.3 mH

Frequency: 2.5 kHz

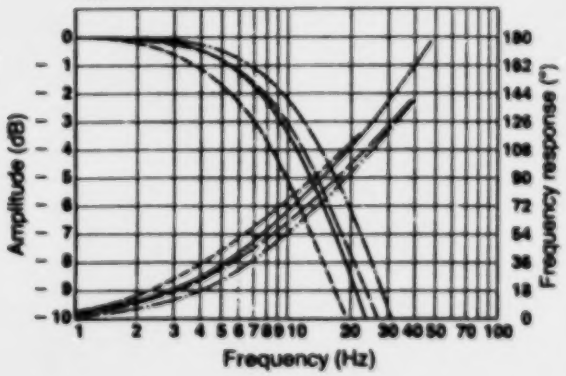
Matching Amplifier for Type 4 WRD 32...:
VT 1610, set for 4 WRD 32

Frequency Response Curves (measured at v = 36 mm^2/s and t = 50 °C)

Type 4 WRD 32 ...

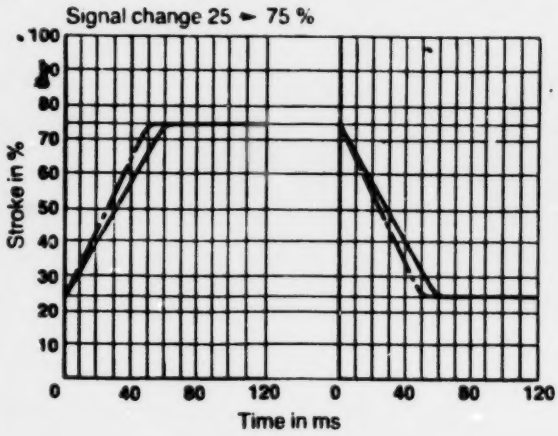


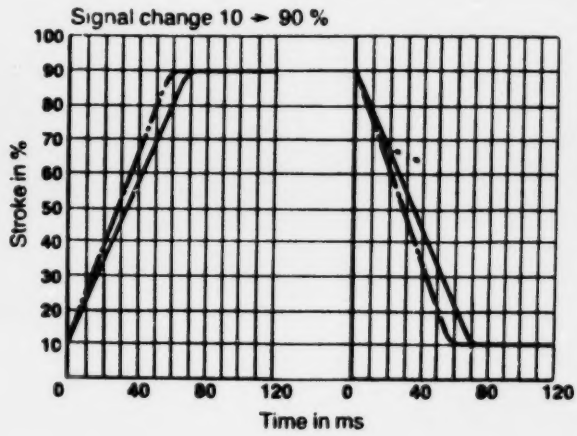
Type 4 WRDE 32 ...

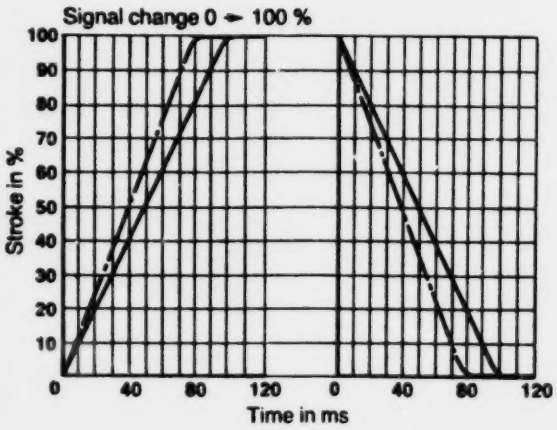


——— P_{st} = 70 bar; u (t) = 5 V ± 0,5 V cos (ωt)
– – – – – – – P_{st} = 70 bar; u (t) = 5 V ± 2,5 V cos (ωt)
——·——·—— P_{st} = 160 bar; u (t) = 5 V ± 0,5 V cos (ωt)
—— —— —— P_{st} = 160 bar; u (t) = 5 V ± 2,5 V cos (ωt)

Crossover Function with Stepped Electrical Input Signal

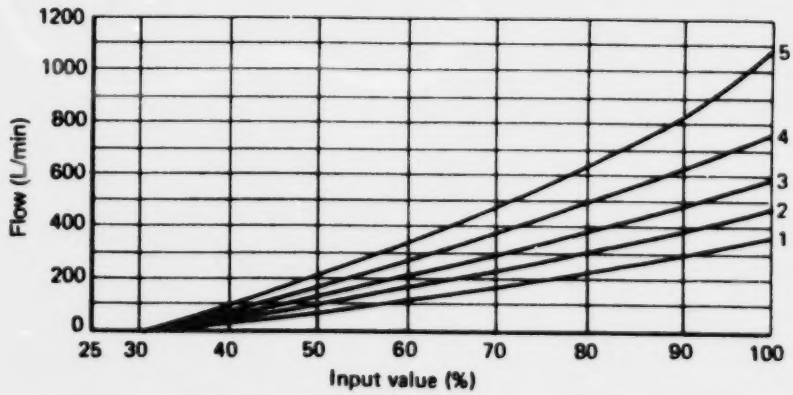






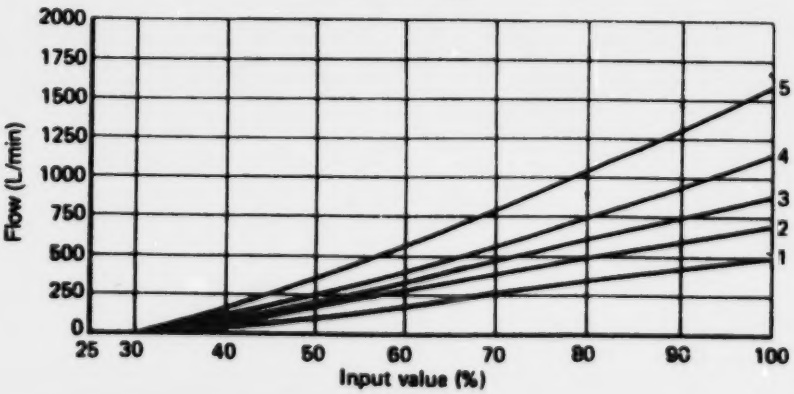
Pilot pressure p = 70 bar ——
Pilot pressure p = 150 bar —·—

Operating Curves (measured at ν = 36 mm²/s and t = 50 °C)



360 L/min nominal flow at 10 bar pressure drop across the valve

1 p_V = 10 bar const.
2 p_V = 20 bar const.
3 p_V = 30 bar const.
4 p_V = 50 bar const.
5 p_V = 100 bar const.

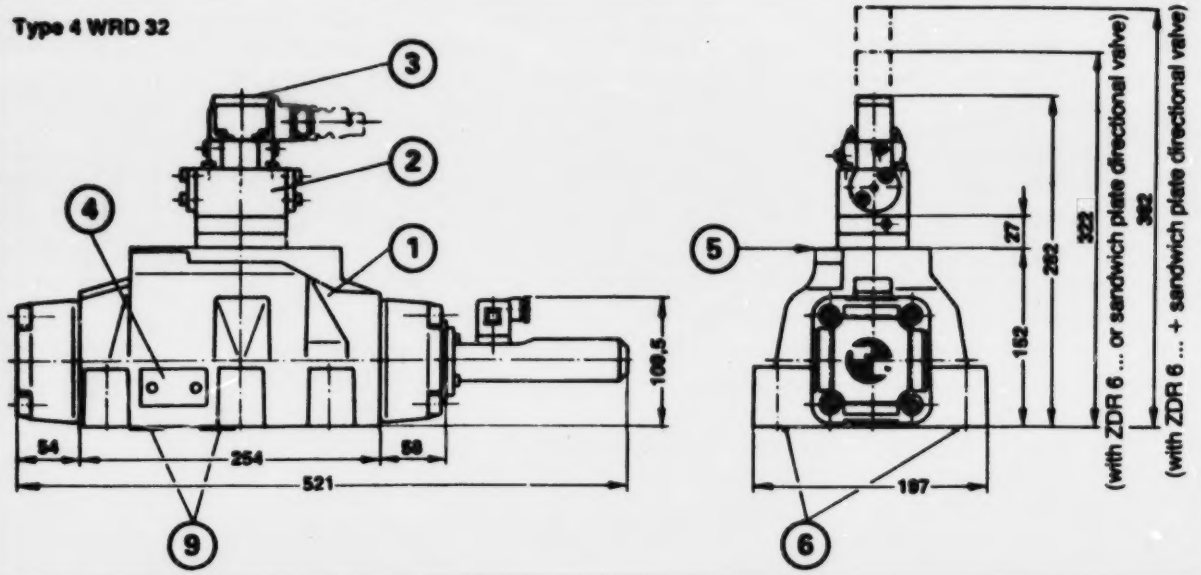


520 L/min nominal flow at 10 bar pressure drop across the valve

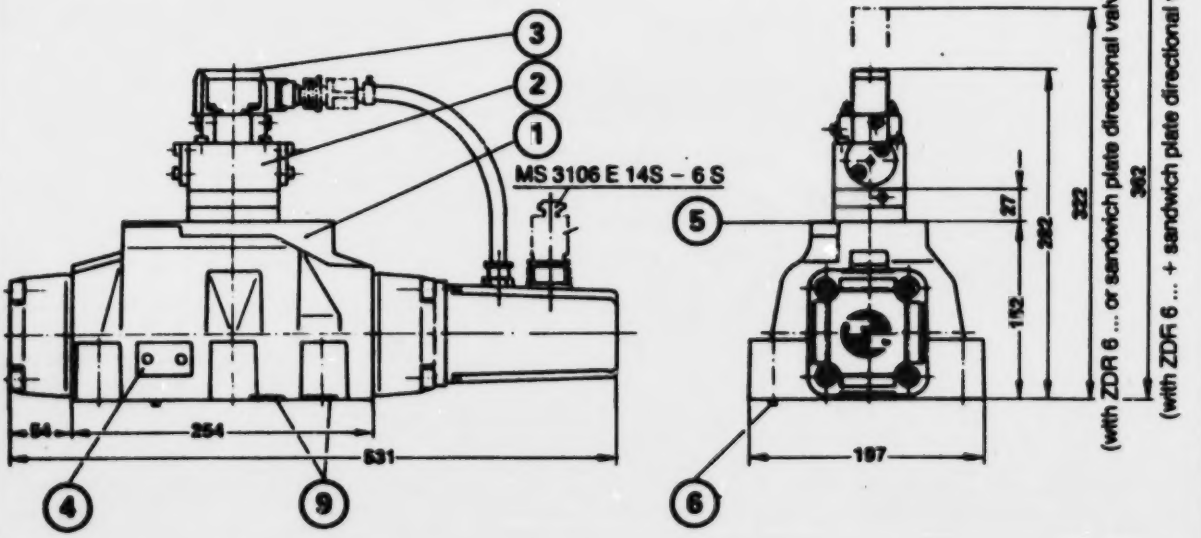
1 p_V = 10 bar const.
2 p_V = 20 bar const.
3 p_V = 30 bar const.
4 p_V = 50 bar const.
5 p_V = 100 bar const.

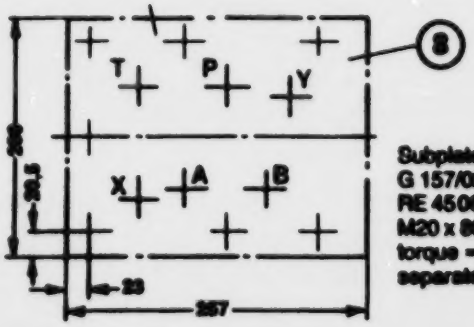
Unit Dimensions: (Dimensions in mm)

Type 4 WRD 32



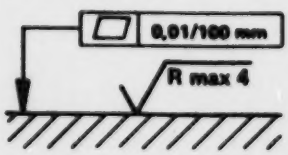
Type 4 WRDE 32





Subplates G 157/01 (1 1/2" BSP), G 157/02 (M48x2), to catalogue sheet RE 45060 and 6 off valve fixing screws M20 x 80, DIN 912-10.9 (tightening torque = 530 Nm) must be ordered separately.

Required surface finish of mounting face



1 Main valve
2 Pilot valve for 3 control positions
3 Nameplate for pilot valve
4 Nameplate for complete valve
5 Pressure reducing valve Type ZDR 6 DR 2-30/150 YM
6 Locating pin
7 Position of pilot valve connections
8 Machined valve mounting face with position of main valve connections
9 O-ring 42 x 3 for A, B, P and T
O-ring 19 x 3 for X and Y
10 Sandwich plate directional valve

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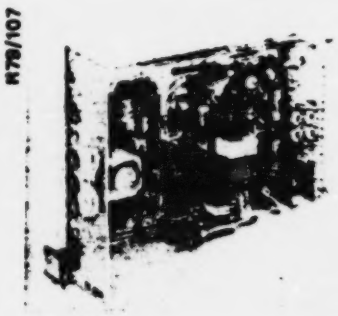
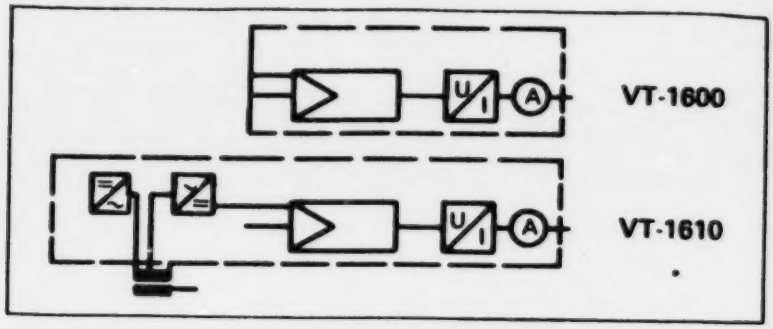
Subject to revision

Servo Amplifier VT-1600 – Type VT-1610 with Additional Oscillator/Demodulator Card



VT-1600



Servo amplifiers type VT-1600 serve to control servo valves. The P-I-D controller is uncoupled by changing an internal bridge; the following fixed current generator can therefore be directly controlled. The ammeter fitted in the front plate shows the servo valve current directly.

The servo amplifier type VT-1610 has an additional oscillator/demodulator card, which can be plugged in. It serves to control valves with inductive displacement transducer.

Type		VT-1600	VT-1610
Supply voltage	(U)	± 22 ÷ 28 V stabilised	
Input voltage	(U)	± 12 V	
Output current	(I_{max})	60 mA	
Oscillator frequency	(f)	–	2,5 kHz
Dither frequency		200 Hz/3 mA_{ss}	
Temperature range	(t)	0° C – + 50° C	
Plug connection		indirect/DIN 41 612/Model D/32 pin	
Space required		8 divisions	
Euro design		100 x 160 mm	

REXROTH
WORLDWIDE HYDRAULICS
MOBILE HYDRAULICS DIVISION
Wooster, Ohio
216/262-2010
INDUSTRIAL HYDRAULICS DIVISION
Bethlehem, Pa
215/694-8300

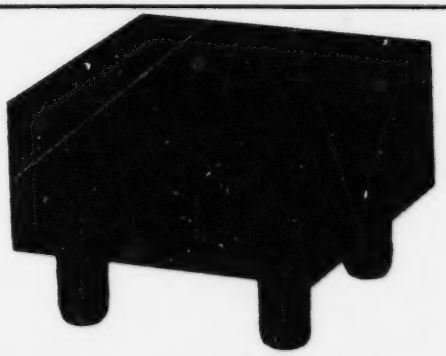
2/2 WAY CARTRIDGE VALVE LC 50
COVER LFA 50
TO DIN 24342

RA 81062

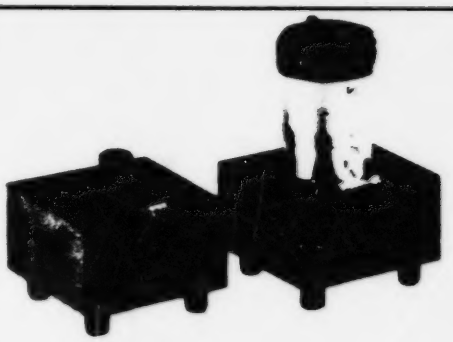
SIZE 5 (2-1/2")	UP TO 6000 PSI	UP TO 530 GPM	ISSUED 10-81

- Valve poppet with or without cushioning shoulder
- Two area ratios
- Nine possible cracking pressures
- Four stroke limiters
- Cover with built-in poppet valve
- Cover with built-in changeover valve
- Cover for fitting directional spool valves with or without built-in changeover valve
- Cover for fitting directional poppet valves with or without built-in changeover valve
- Cover with position control, on request

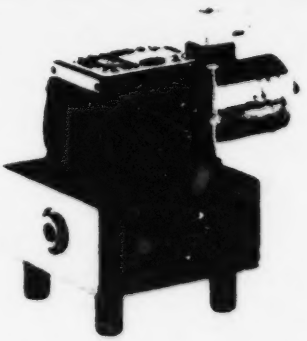
2/2 way cartridge valve LC 50..-50/..



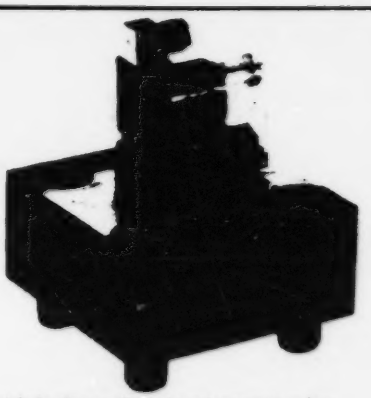
Cover with remote control port LFA 50 D-50/..F..



Cover with stroke limiter. H2. H4



Cover with built-on directional spool valve
LFA 50 WE..-50/..



Cover with built-on directional poppet valve
LFA 50 SE..-50/..

2/2 way cartridge valves comprise mainly a cover (1) and a cartridge assembly (2).

The cover houses the control bores and either a stroke limiter, directional poppet valve or changeover valve, depending on the function required. Directional spool valves or directional poppet valves can be fitted on the cover. The cartridge assembly is comprised of a sleeve (3) a valve poppet (4), optionally with cushioning shoulder (5) or without cushioning shoulder (6), also a closing spring (7).

Function

2/2 way cartridge valves are purely pressure related. There are therefore three important function surfaces: A1, A2 and A3.

The surface at the valve poppet A1 is regarded as being 100%.

The annulus area A2 is, at area ratio 2:1, 50% of surface A1, and at area ratio 14.3:1, 7% of the surface A1.

Surface A3 = the sum of surface A1 and A2. It is always of equal size.

Because of the different area ratios A1:A2 and the difference annulus areas (A2) resulting from this, surface A3 is either 107% or 150% of the surface A1 (100%).

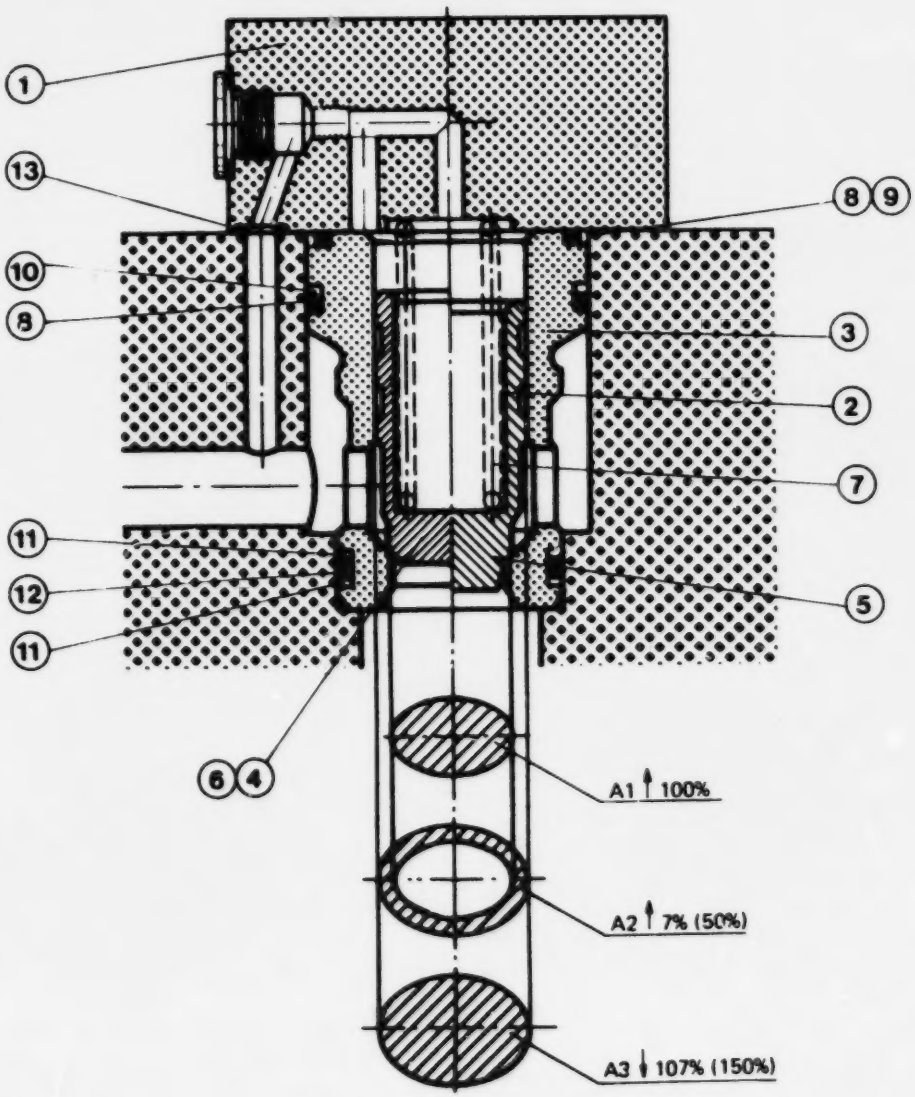
Oil can flow through 2/2 way cartridge valves from A to B or from B to A.

Port A is closed leakfree when surface A3 is pressurized by pilot oil taken from port B or external pilot oil supply.

The control of the valve poppet is related to the built-on cover and the control bores in the block.

The following is generally valid:

The 2/2 way cartridge valve opens when, corresponding to the direction of flow, the force affecting surfaces A1 or A2 is greater than the force affecting surface A3.



SEAL ELEMENTS AND SPRINGS: Dimensions in Millimeters

RA 81062

Seal elements

Item	Description	Seal material NBR		Seal material O-rings Viton Back-up ring: Teflon	
		Dimensions	Part Number	Dimensions	Part number
8	O-Ring	78,75 x 5,33	008 035	78,75 x 5,33	009 114
9	Back-up ring	92,1x4,6(Teflon)	153 571	92,1 x 4,6	153 571
10	Back-up ring	79,83 x 4,65	001 897	78 x 87 x 1,5	001 903
11	Back-up ring	60,88 x 3	001 893	60,2 x 66 x 1	002 806
12	O-Ring	59,92 x 3,53	008 765	59,92 x 3,53	002 536
13	O-Ring	12,37 x 2,62	004 489	12,37 x 2,62	008 949
Seal kit, comprising items 8, 9, 10, 11, 12 and 13		314 056		314 065	

Springs

Cracking pressures at area ratio 2 : 1		14,3 : 1		Type number	Spring dimensions	Part number
6.5 PSI	* 7.2 PSI	4.6 PSI	* 5.0 PSI	05	36/3,2 x 130/10,5	002 123
12.6 PSI	* 14.5 PSI	9.1 PSI	* 10.1 PSI	10	35,5/3,6 x 130/9	002 124
25.2 PSI	* 29.0 PSI	18.2 PSI	* 20.3 PSI	20	34,5/4,5 x 130/12	002 125
48.5 PSI	* 58.0 PSI	35.2 PSI	* 40.6 PSI	40	33,5/5,6 x 117/10	002 126

TECHNICAL DETAILS

Hydraulic medium		Petroleum based hydraulic fluids phosphate ester						
Fluid temperature range		-4...158°F						
Viscosity range		35 to 1750 SSU						
Operating pressure at ports A, B, X, Z1, and Z2	PSI	4000 (cover with built-on directional spool valve; cover with built-on directional poppet valve, 4000 PSI model)						
	PSI	6000 (cover without built-on directional control valves; cover with built-on directional poppet valve, 9000 PSI model)						
Operating pressure at port Y	PSI	* tank pressure of the built-on valves						
Cracking pressures at:		Area ratio 2:1				Area ratio 14:3:1		
Flow direction		A → B		B → A		A → B		B → A
Spring model 00 (effective spool weight)	PSI	0.7		1.4		0.5		7.2
Spring model 05	PSI	6.5	7.2	13.4	14.5	4.6	5.0	62.3	72.5
Spring model 10	PSI	12.6	14.5	26.1	29.0	9.1	10.1	121.8	145.0
Spring model 20	PSI	25.2	29.0	52.2	58.0	18.2	20.3	242.1	290.0
Spring model 40	PSI	48.5	58.0	100.0	116.0	35.2	40.6	466.9	580.0
Surface A1	(cm^2)	16,6				22,9			
Surface A2	(cm^2)	8,03				1,73			
Surface A3	(cm^2)	24,63							
Poppet type		with cushioning shoulder (item 5)				without cushioning shoulder (item 6)			
Stroke H	(cm)	2				1,6			
Pilot volume	(cm^3)	49,2				39,4			
Pilot flow required at a switching time of 10 ms GPM		77.93				62.08			
Weight – cartridge assembly	lbs.	8.3							
– standard cover	lbs.	23.1							

For applications to other specifications, please consult us.

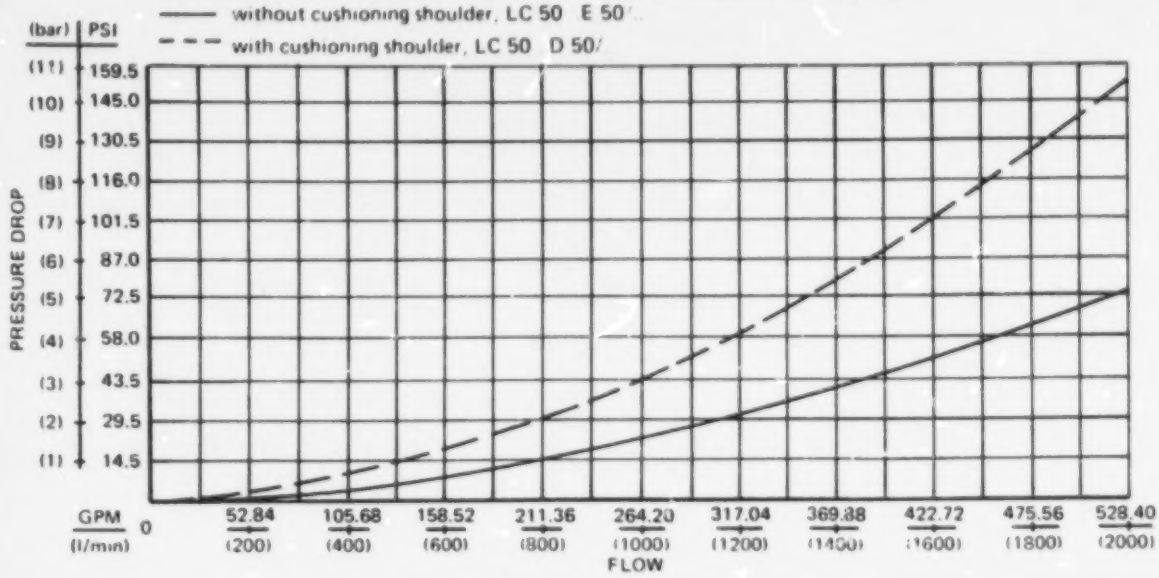
***These cracking pressures are valid for models with stroke limiter H2 and H4.**

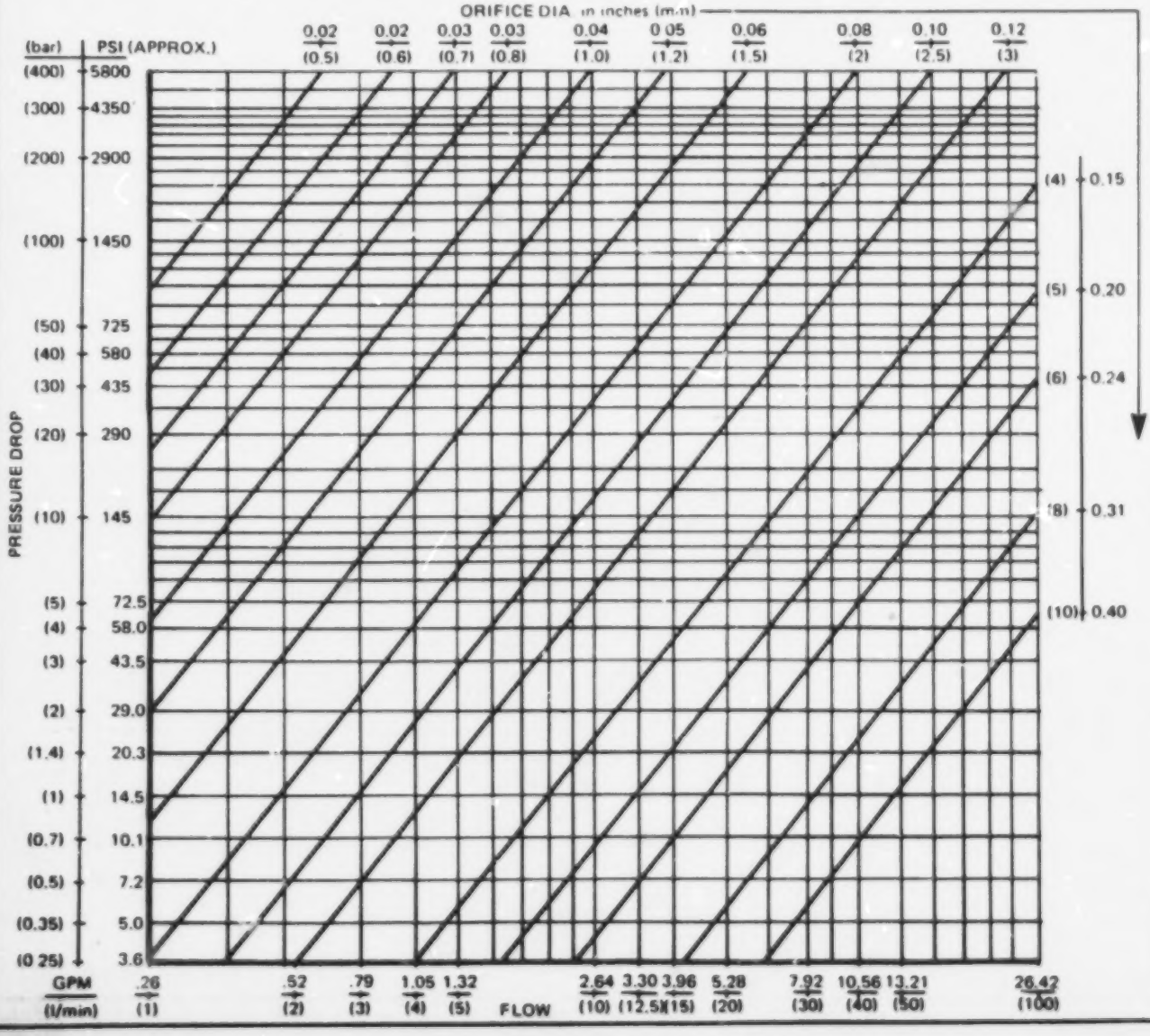
PERFORMANCE CURVES (Measured at v = 167.7 SSU and t = 122°F) **RA 81082**

Δp - Q curves for the 2/2 way cartridge valve without consideration of the spring

——— without cushioning shoulder, LC 50 E 50/..

– – – with cushioning shoulder, LC 50 D 50/





ORDERING DETAILS FOR 2/2 WAY CARTRIDGE VALVES

RA 81062

LC 50				50	/	•

Area ratio 2:1 (annulus area = 50%) = A
Area ratio 14,3:1 (annulus area = 7%) = B

Cracking pressures at area ratio 2:1		14,3:1		
without spring				00
6.5 PSI	* 7.2 PSI	4.6 PSI	* 5.0 PSI	05
12.6 PSI	*14.5 PSI	9.1 PSI	*10.1 PSI	10
25.2 PSI	*29.0 PSI	18.2 PSI	*20.3 PSI	20
48.5 PSI	*58.0 PSI	35.2 PSI	*40.6 PSI	40

* These cracking pressures are valid for models with stroke limiter H2 and H4

Further details to be stated in text

no desig. Petroleum based hydraulic fluids
V = phosphate ester

50 = series 50
(50 - 59 = installation and connection dimensions remain the same)

E = valve poppet without cushioning shoulder
D = valve poppet with cushioning shoulder

UNIT DIMENSIONS : Dimensions in Millimeters

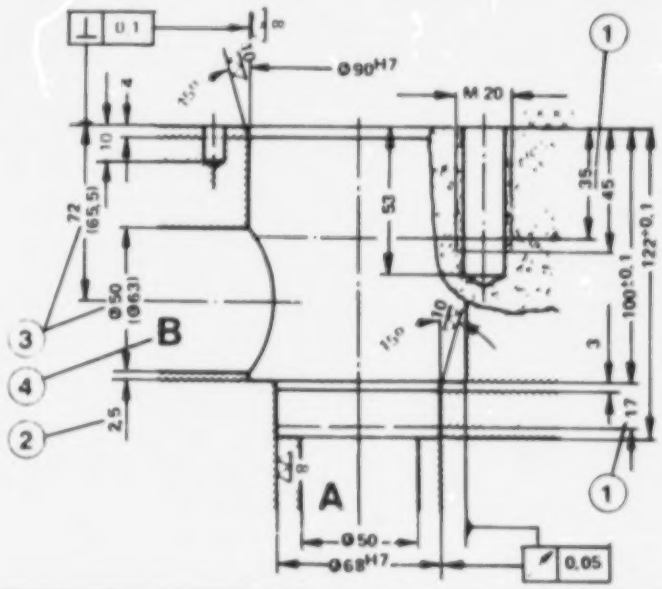
Assembly bore for 2/2 way cartridge valves

1 depth of fit

2 control dimension

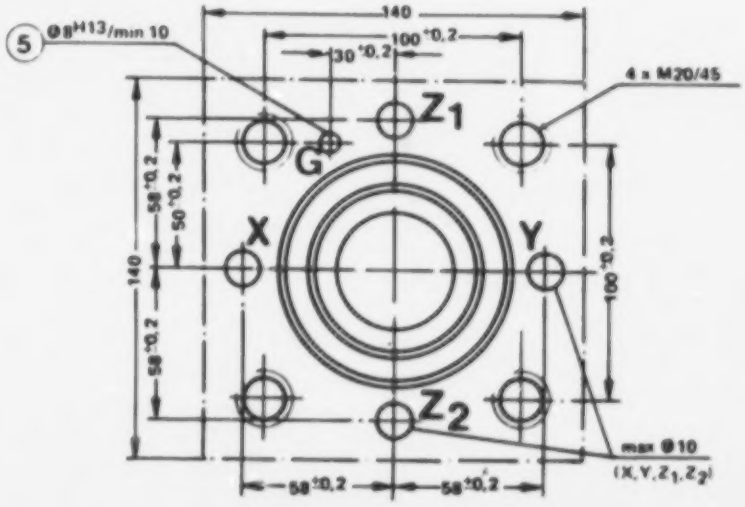
3 If the diameter of port B is other than 50 or 63, the distance from the cover contact surface to the middle of the bore must be calculated

4 Port B can be positioned around the center axis of port A. However, care must be taken to avoid damaging the bolt holes and control holes



Porting pattern for the cover of the 2/2 way cartridge valve

5 Bore for locating pin



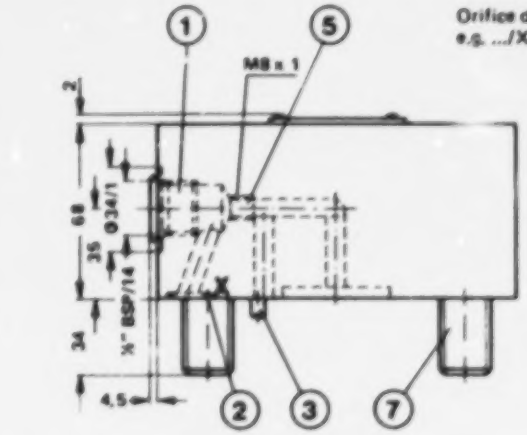
COVER WITH REMOTE CONTROL CONNECTION: Dimensions in Millimeters RA 81062

LFA 50 D 50 / F [ ] [ ] [ ] *

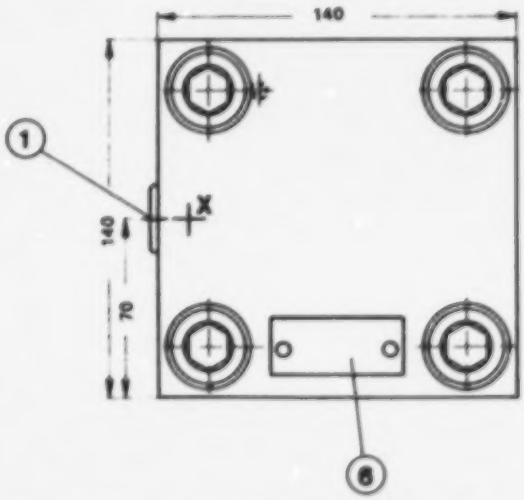
Further details to be stated in text

without orifice = no desig.
orifice in line X + orifice dia. * = X ...

no desig. = Petroleum based hydraulic fluids
V = phosphate ester



Orifice dia. in 1/10 mm,
e.g. .../X12 = orifice dia. 1.2 mm



1 Port X optionally as threaded connection

2 O-ring 12.37 x 2.62

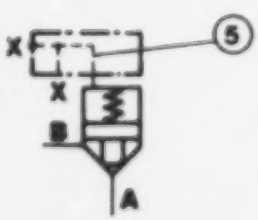
3 Locating pin

5 Provision for fitting of an orifice (3/8" BSP)

6 Nameplate

7 4 off S.H.C.S. M30 x 100
Md = 1328.4 ft/lbs, included in extent of supply

LFA 50 D 50/F..



COVER WITH STROKE LIMITER, WITH OR WITHOUT REMOTE CONTROL CONNECTION: Dimensions in Millimeters **RA 81062**

LFA 50	– 50 / F			•

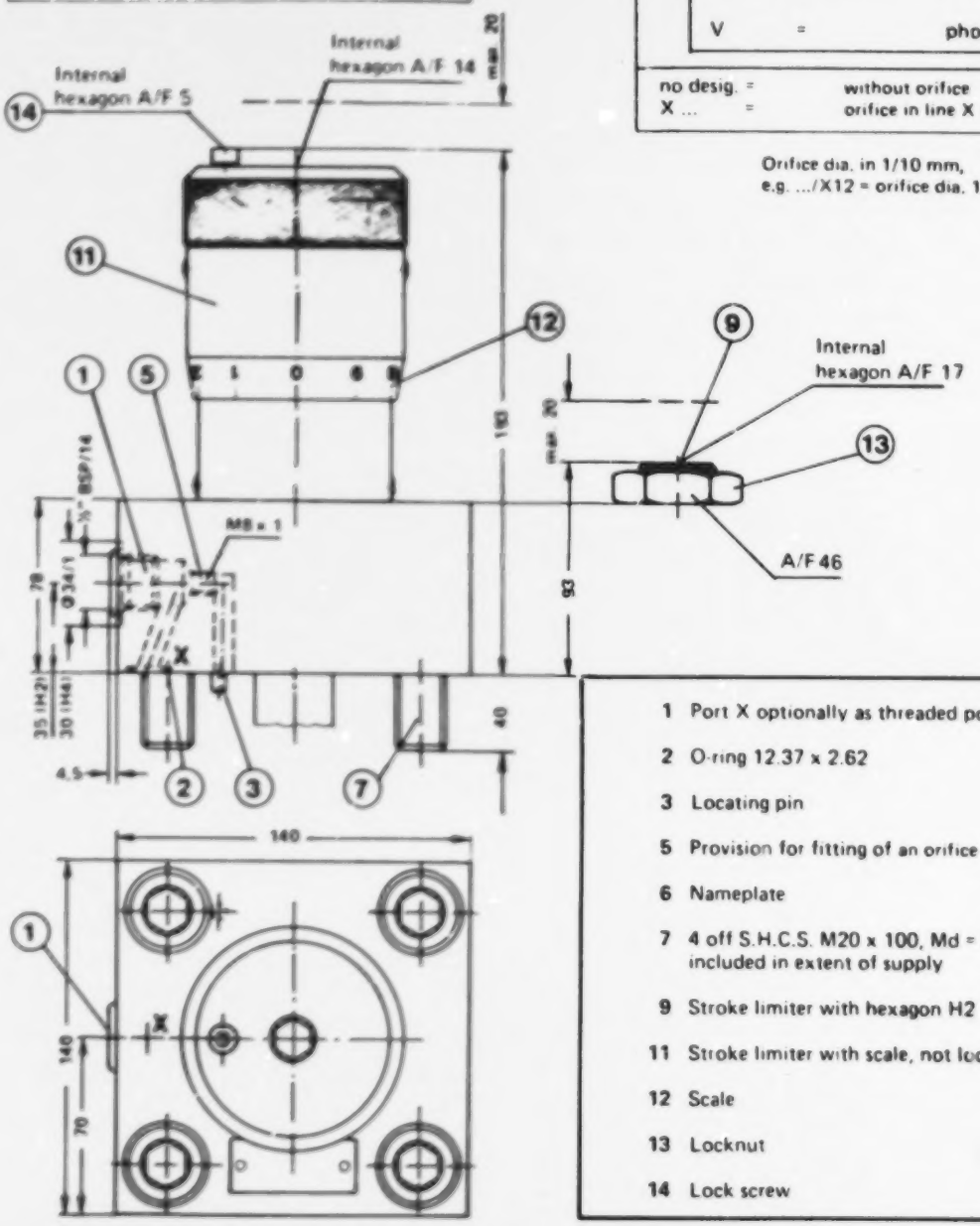
Further details to be stated in text

no desig = Petroleum based hydraulic fluids
V = phosphate ester

no desig. = without orifice
X ... = orifice in line X + orifice dia.

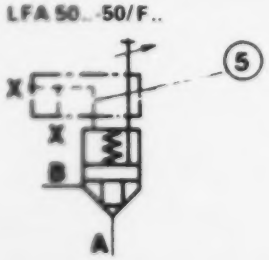
Orifice dia. in 1/10 mm,
e.g. .../X12 = orifice dia. 1.2 mm

Stroke limiter with hexagon socket = H2
Stroke limiter with scale, not lockable = H4



1 Port X optionally as threaded port
2 O-ring 12.37 x 2.62
3 Locating pin
5 Provision for fitting of an orifice M8 x 1
6 Nameplate
7 4 off S.H.C.S. M20 x 100, Md = 383.7 ft/lbs, included in extent of supply
9 Stroke limiter with hexagon H2
11 Stroke limiter with scale, not lockable, H4
12 Scale
13 Locknut
14 Lock screw

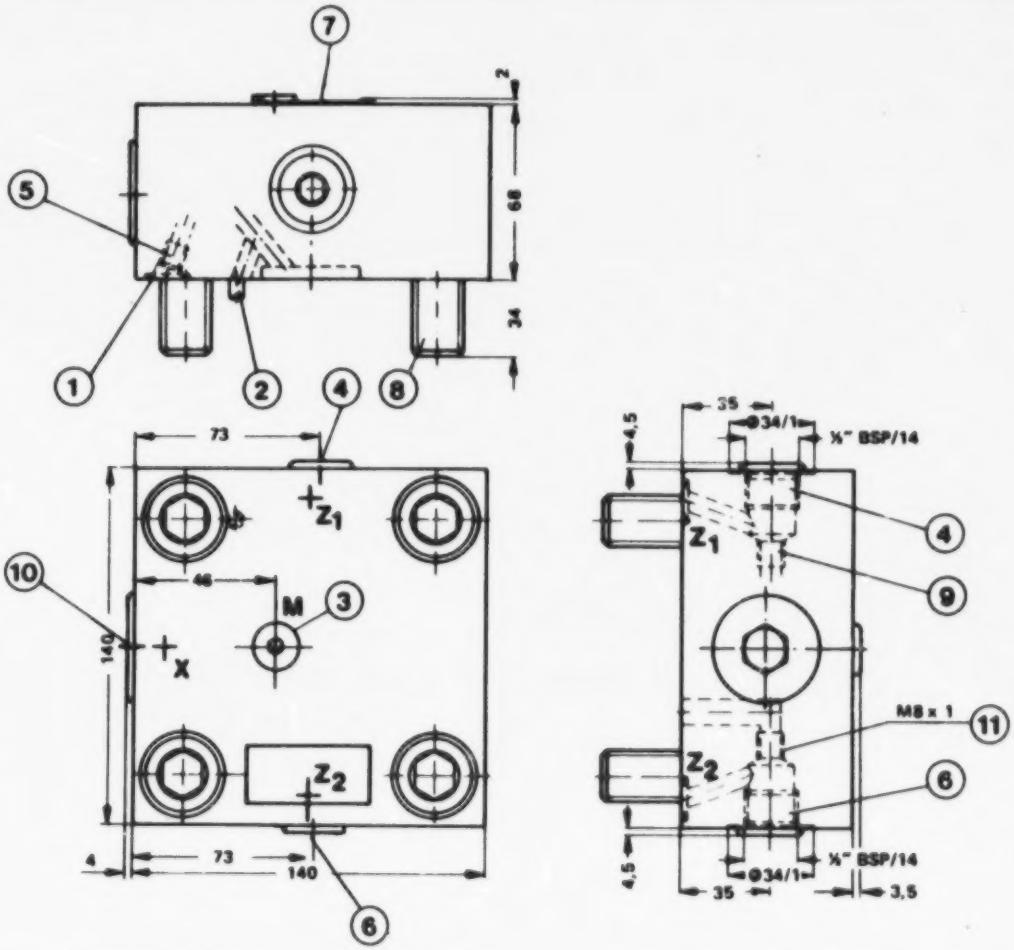
LFA 50..-50/F..



LFA 50 G 50	/	*

Petroleum based hydraulic fluids	= no desig.
phosphate ester	V

Further details to be stated in text



1 O-ring 12.37 x 2.62 at ports X, Z1 and Z2

2 Locating pin

3 Measuring port, 1/4" BSP

4 Port Z1, optionally as threaded port

5 Orifice, dia. 1.5 (M8 x 1 spherical)

6 Port Z2, optionally as threaded port

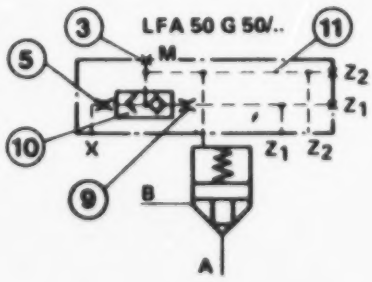
7 nameplate

8 4 off S.H.C.S. M20 x 80, Md = 383.7 ft/lbs, included in extent of supply

9 Orifice, dia. 1.5 (M8 x 1 spherical)

10 Changeover valve size 10

11 Provision for fitting of an orifice (M8 x 1 spherical)



COVER WITH BUILT-IN DIRECTIONAL POPPET VALVE: Dimensions in Millimeters

RA 81082

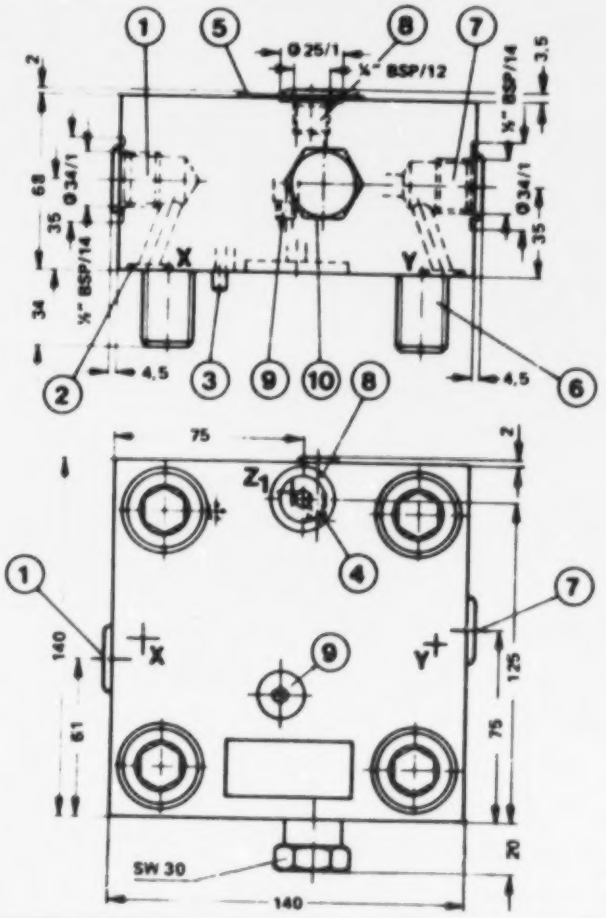
LFA 50 R 50 / [ ] [ ] *

Without orifice	= no desig.
Orifice in bore to spring chamber F + orifice dia.	* = F ...

Petroleum based hydraulic fluids	=no desig.
Phosphate ester	= V

Further details to be stated in text

Orifice dia. in 1/10 mm
e.g. .../F12 = orifice dia. 1.2 mm



1 Port X optionally as threaded port

2 O-ring 12.37 x 2.62 on ports X, Y and Z1

3 Locating pin

4 Orifice 1.2 (M8 x 1 spherical)

5 Nameplate

6 4 off S.H.C.S. M20 x 80, Md = 383.7, ft/lbs, included in extent of supply

7 Port Y optionally as threaded port

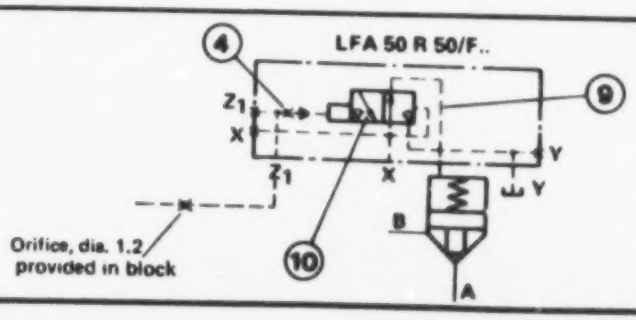
8 Port Z1 optionally as threaded port

9 Provision for fitting of an orifice (M8 x 1 spherical)

10 Hydraulically operated poppet valve size 10

Area ratio

$$\frac{A_{Z1}}{A_X} = \frac{3}{1}$$



COVER FOR FITTING A DIRECTIONAL SPOOL VALVE: Dimensions in Millimeters RA 81062

LFA 50		50/		•

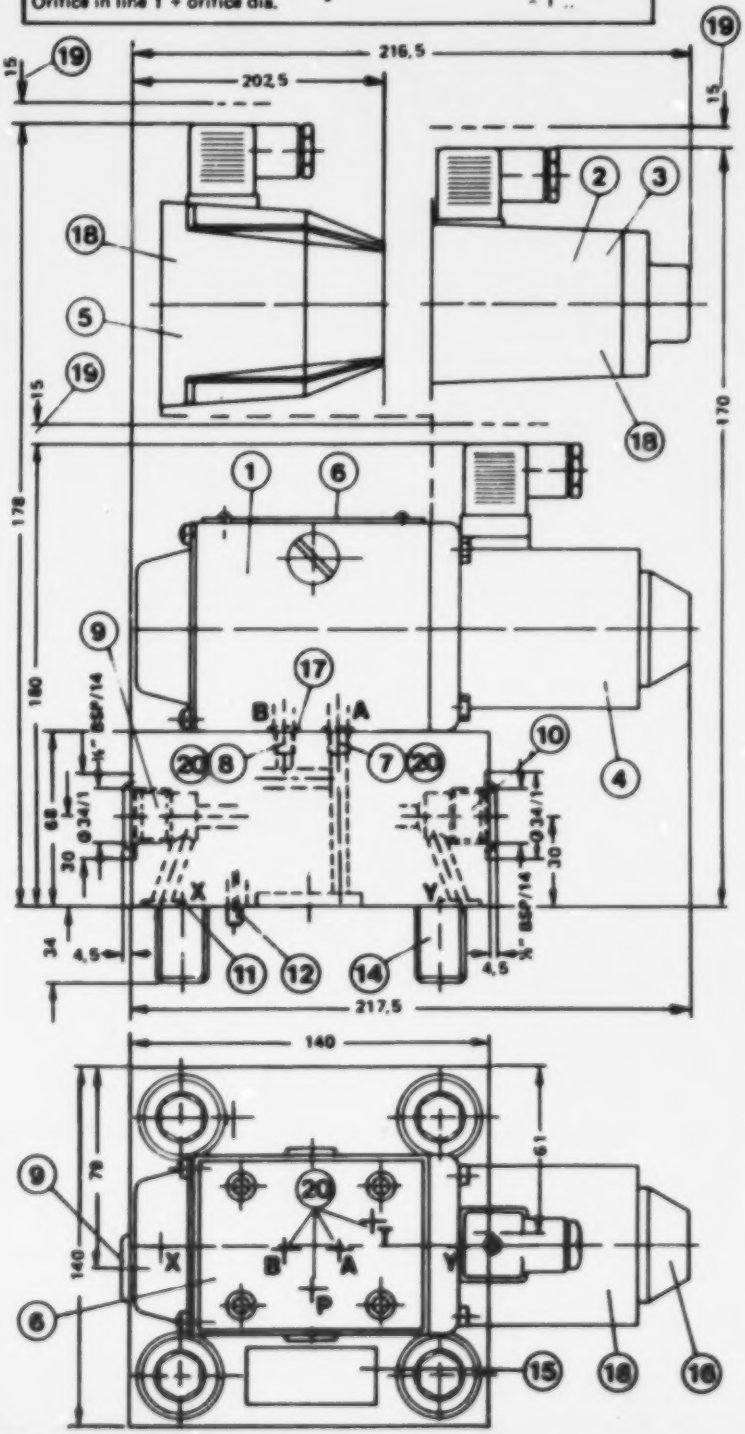
Normally closed (with directional spool valve 4 WE 10 D 1X/..)	= WEA
Normally open (with directional spool valve 4 WE 10 D 1X/..)	= WEB

Without orifice		= no desig.
Orifice in line A + orifice dia.	•	= A ...
Orifice in line B + orifice dia.	•	= B ...
Orifice in line P + orifice dia.	•	= P ...
Orifice in line T + orifice dia.	•	= T ..

Further details to be stated in text

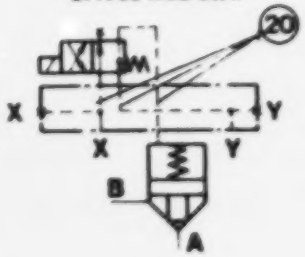
no desig.	=	Petroleum based hydraulic fluids
V	=	phosphate ester

* Orifice dia. in 1/10 mm,
e.g. .../A12 = orifice dia. 1.2 mm

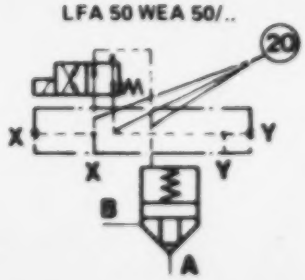


1 Directional valve 4 WE 10 D1X/NZ4.. must be ordered separately
2 DC oil immersed solenoid (RA 23 310)
3 AC oil immersed solenoid (RA 23 312)
4 DC air gap solenoid (RA 23 330)
5 Ac air gap solenoid (RA 23 332)
6 Directional valve nameplate
7 Set screw M8 x 1, spherical, not for type LFA 50 WEA5X/..
8 Set screw M8 x 1, spherical, not for type LFA 50 WEB5X/..
9 Port X optionally as threaded port
10 Port Y optionally as threaded port
11 O-ring 12.37 x 2.62 at ports X and Y
12 Locating pin
14 4 off S H C S M20 x 80, Md = 383.7 ft/lbs , included in extent of supply
15 Nameplate of 2/2 way cartridge valve cover
16 Hand emergency
17 O-ring 12 x 2 at ports A, B, P and T
18 Solenoid a
19 Dimensions for removal of plug
20 Provision for fitting of an orifice (M8 x 1 spherical)

LFA 50 WEB 50/..



LFA 50 WEA 50/..



COVER WITH BUILT-IN CHANGEOVER VALVE, FOR FITTING A DIRECTIONAL POPPET VALVE: Dimensions in Millimeters RA 81062

LFA 50		50		•

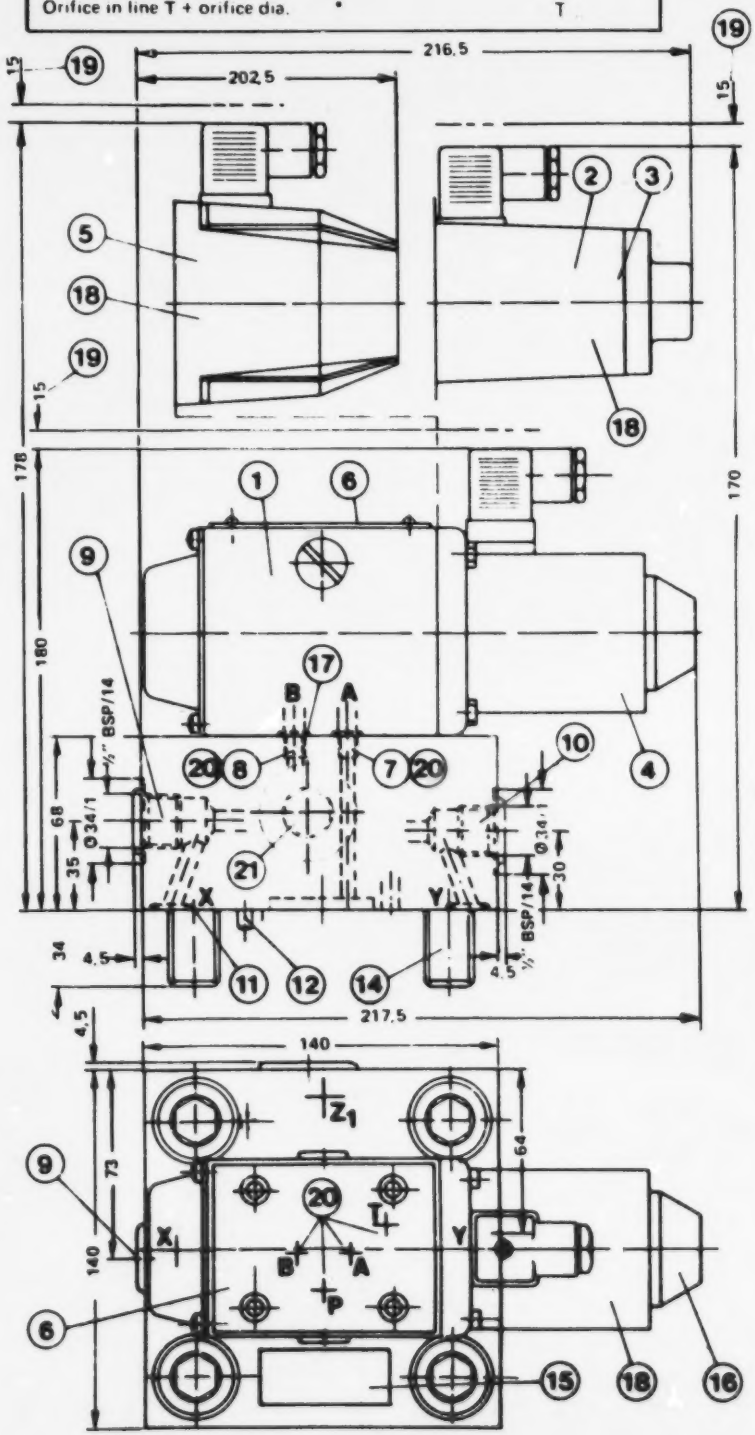
Normally closed (with directional spool valve 4 WE 10 D 1X/..) = GWA
Normally open (with directional spool valve 4 WE 10 D 1X/..) = GWB

Further details to be stated in text

no desig. = Petroleum based hydraulic fluids
V = phosphate ester

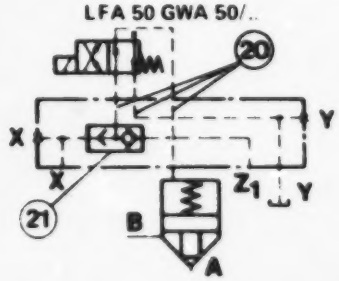
Without orifice		= no desig
Orifice in line A + orifice dia.	•	A
Orifice in line B + orifice dia.	•	B
Orifice in line P + orifice dia.	•	P
Orifice in line T + orifice dia.	•	T

• Orifice dia. in 1/10 mm, e.g. .../A12 = orifice dia. 1.2 mm

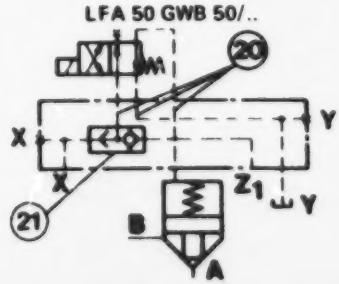


1 Directional valve 4WE 10 D1X/NZ4.. must be ordered separately
2 DC oil immersed solenoid (RA 23 310)
3 AC oil immersed solenoid (RA 23 312)
4 DC air gap solenoid (RA 23 330)
5 AC air gap solenoid (RA 23 332)
6 Nameplate of directional valve
7 Set screw M8 x 1 spherical, not for type LFA 50 GWA 5X/..
8 Set screw M8 x 1 spherical, not for type LFA 50 GWB 5X/..
9 Port X optionally as threaded port
10 Port Y optionally as threaded port
11 O-ring 12.37 x 2.62 at ports X, Y and Z1
12 Locating pin
14 4 off S H C.S. M20 x 80, Md = 383.7 ft/lbs , included in extent of supply
15 Nameplate of 2/2 way cartridge valve cover
16 Hand emergency
17 O-ring 12 x 2, at ports A, B, P and T
18 Solenoid a
19 Dimension for removal of plug
20 Provision for fitting of an orifice (M8 x 1 spherical)
21 Changeover valve size 10

LFA 50 GWA 50/..



LFA 50 GWB 50/..



COVER WITH BUILT-IN CHANGEOVER VALVE, FOR FITTING A DIRECTIONAL SPOOL VALVE: Dimensions in Millimeters RA 81062

LFA 50		50		*

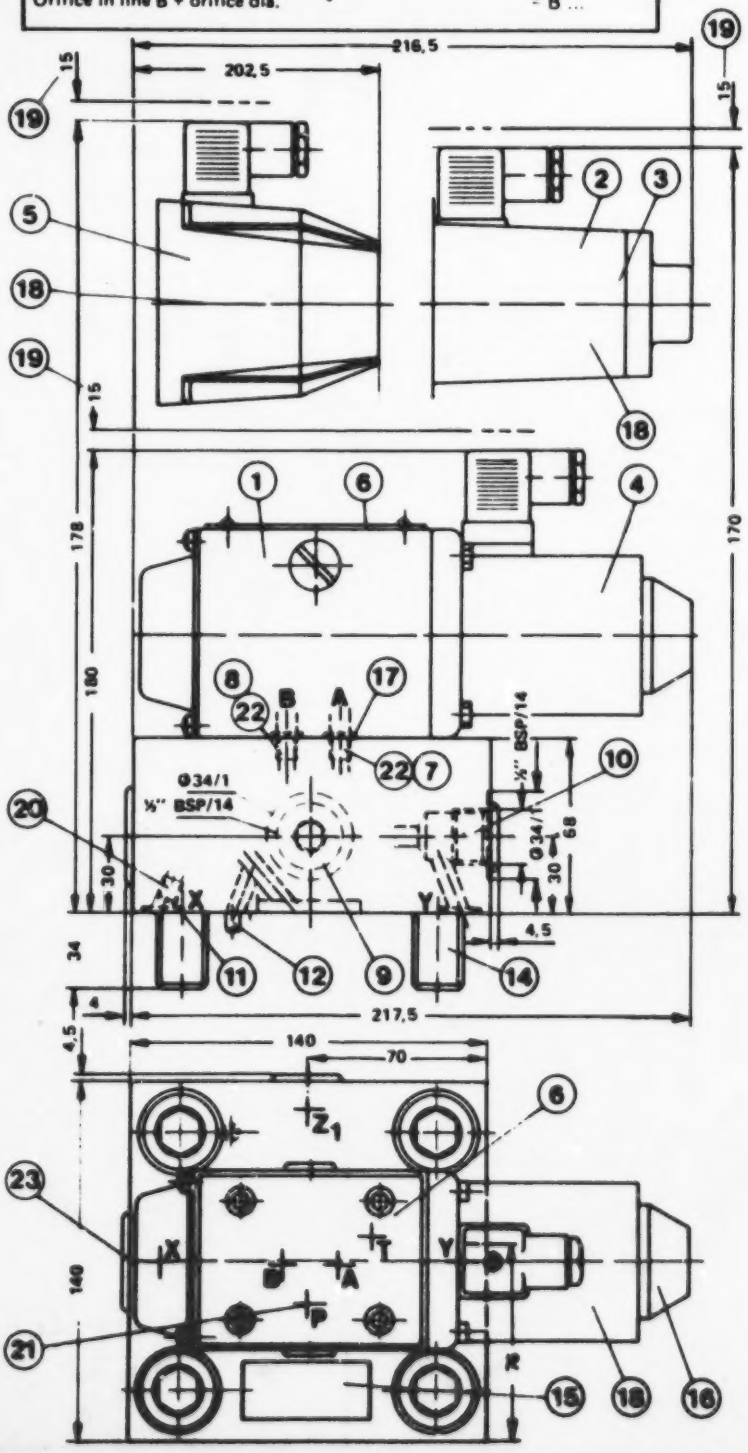
Normally closed (with directional spool valve 4WE 10D1X/..) = KWA
Normally open (with directional spool valve 4WE10D1X/..) = KWB

Without orifice = no desig.
Orifice in line A + orifice dia. * = A ...
Orifice in line B + orifice dia. * = B ...

Further details to be stated in text

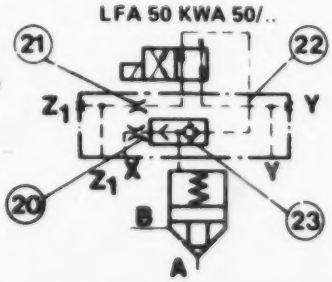
no desig. = Petroleum based hydraulic fluids
V = phosphate ester

* Orifice dia. in 1/10 mm
e.g. .../A12 = orifice dia. 1.2 mm

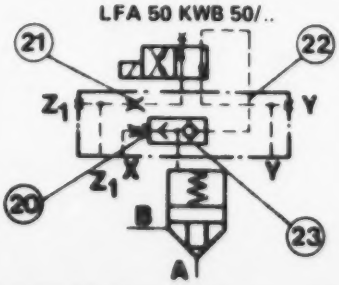


1	Directional valve 4 WE 10 D1X/NZ4., must be ordered separately
2	DC oil immersed solenoid (RA 23 310)
3	AC oil immersed solenoid (RA 23 312)
4	DC air gap solenoid (RA 23 330)
5	AC air gap solenoid (RA 23 332)
6	Directional valve nameplate
7	Set screw M8 x 1 spherical, not for type LFA 50 KWA5X/..
8	Set screw M8 x 1 spherical, not for type LFA 50 KWB5X/..
9	Port Z1 optionally as threaded port
10	Port Y optionally as threaded port
11	O-ring 12.37 x 2.62 for ports X, Y and Z1
12	Locating pin
14	4 off S.H.C.S. M20 x 80, Md = 383.7 ft/lbs , included in extent of supply
15	Nameplate of 2/2 way cartridge valve
16	Hand emergency
17	O-ring 12 x 2, for ports A, B, P and T
18	Solenoid a
19	Dimension for removal of plug
20	Orifice, dia. 1.5 (M8 x 1 spherical)
21	Orifice, dia. 1.5 (M8 x 1 spherical)
22	Provision for fitting of an orifice (M8 x 1)
23	Changeover valve size 10

LFA 50 KWA 50/..



LFA 50 KWB 50/..



COVER FOR FITTING A DIRECTIONAL POPPET VALVE: Dimensions in Millimeters RA 81062

LFA 50		50				•

Normally closed = SEA
(with directional poppet valve M 3 SE 10U2X)
Normally open = SEB
(with directional poppet valve M 3 SE 10C2X)

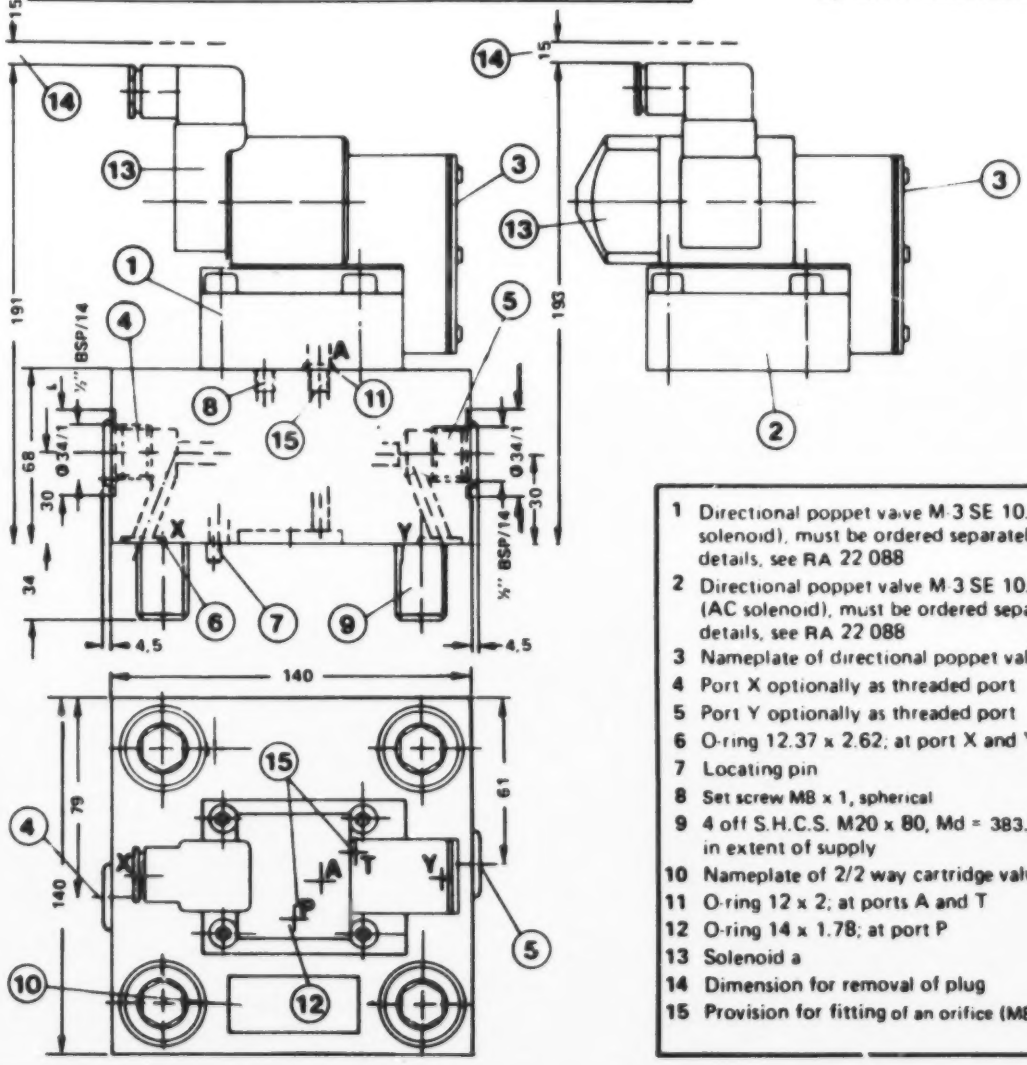
Further details to be stated in text

no desig. = Petroleum based hydraulic fluids
V = phosphate ester

For dir. poppet valve, 4500 PSI model = no desig.
For dir. poppet valve, 9000 PSI model = 630

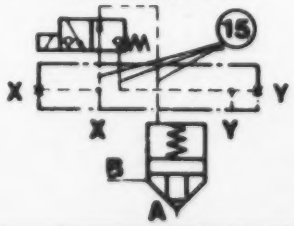
Without orifice = no desig.
Orifice in line A + orifice dia. • = A ...
Orifice in line P + orifice dia. • = P ...
Orifice in line T + orifice dia. • = T ...

Orifice dia. in 1/10 mm,
e.g. .../A12 = orifice dia. 1.2 mm

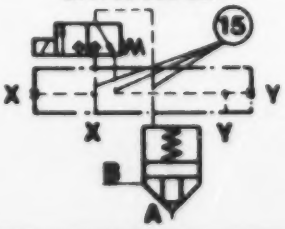


1 Directional poppet valve M 3 SE 10..2X/..G24..Z4 (DC solenoid), must be ordered separately, For further details, see RA 22 088
2 Directional poppet valve M 3 SE 10..2X/..W120-60..Z4 (AC solenoid), must be ordered separately, For further details, see RA 22 088
3 Nameplate of directional poppet valve
4 Port X optionally as threaded port
5 Port Y optionally as threaded port
6 O-ring 12.37 x 2.62; at port X and Y
7 Locating pin
8 Set screw M8 x 1, spherical
9 4 off S.H.C.S. M20 x 80, Md = 383.7 ft/lbs included in extent of supply
10 Nameplate of 2/2 way cartridge valve
11 O-ring 12 x 2; at ports A and T
12 O-ring 14 x 1.78; at port P
13 Solenoid a
14 Dimension for removal of plug
15 Provision for fitting of an orifice (M8 x 1 spherical)

LFA 50 SEA 50/..



LFA 50 SEB 50/..



COVER WITH BUILT-IN CHANGEOVER VALVE FOR FITTING A DIRECTIONAL POPPET VALVE: Dimensions in Millimeters RA 81082

LFA 50		50			•

Normally closed = GSA
(with directional poppet valve M-3 SE10U2X/..)
Normally open = GSB
(with directional poppet valve M-3 SE10C2X/..)

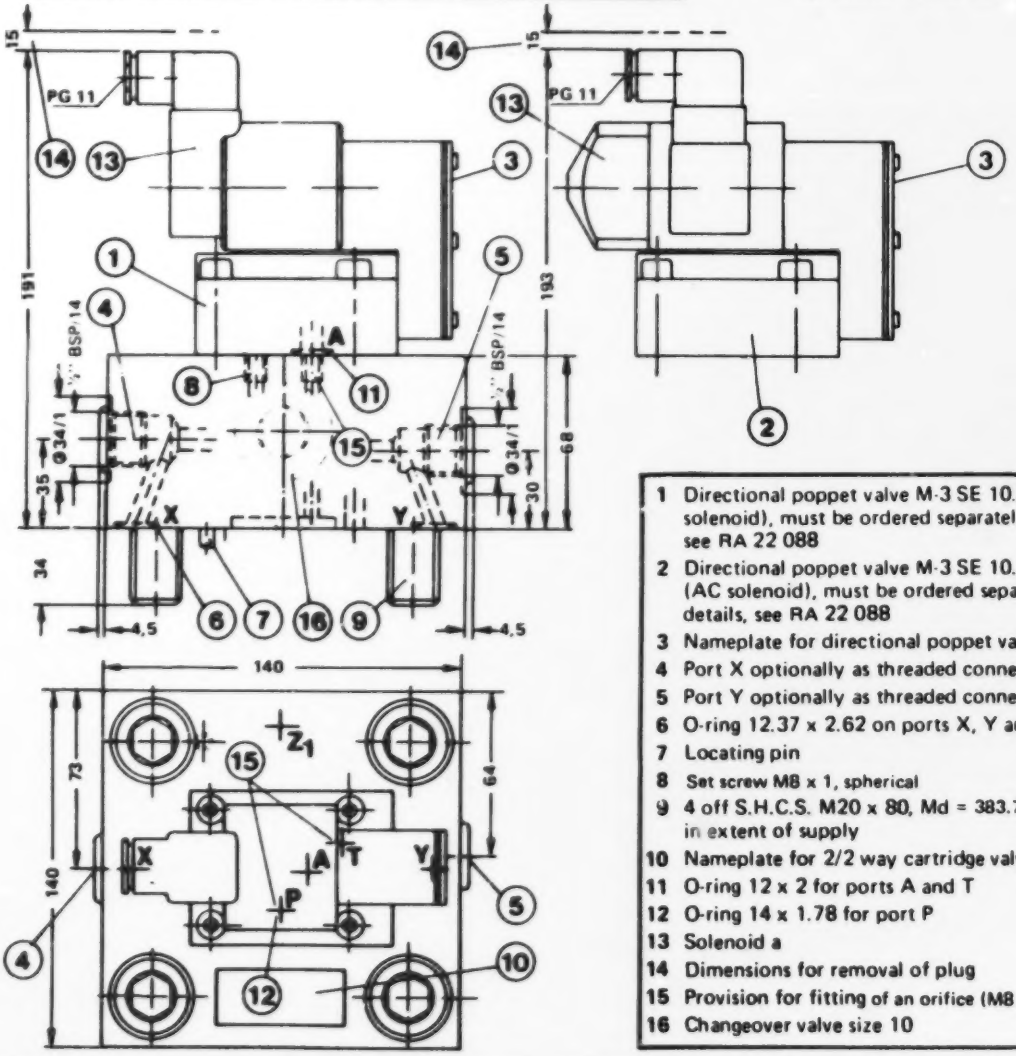
For directional poppet valve, 4500 PSI model = no desig.
For directional poppet valve, 9000 PSI model = 630

Without orifice = no desig.
Orifice in line A + orifice dia. * = A ...
Orifice in line P + orifice dia. * = P ...
Orifice in line T + orifice dia. * = T ...

Further details to be stated in text

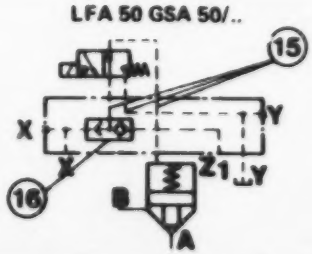
no desig.= Petroleum based hydraulic fluids
V = phosphate ester

* Orifice dia. in 1/10 mm,
e.g. .../A12 = orifice dia. 1.2 mm

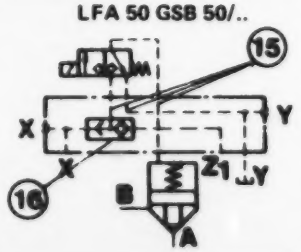


1 Directional poppet valve M-3 SE 10..2X/..G24..Z4.. (DC solenoid), must be ordered separately; for further details, see RA 22 088
2 Directional poppet valve M-3 SE 10..2X/..W120-60..Z4.. (AC solenoid), must be ordered separately; for further details, see RA 22 088
3 Nameplate for directional poppet valve
4 Port X optionally as threaded connection
5 Port Y optionally as threaded connection
6 O-ring 12.37 x 2.62 on ports X, Y and Z1
7 Locating pin
8 Set screw M8 x 1, spherical
9 4 off S.H.C.S. M20 x 80, Md = 383.7 ft/lbs, included in extent of supply
10 Nameplate for 2/2 way cartridge valve cover
11 O-ring 12 x 2 for ports A and T
12 O-ring 14 x 1.78 for port P
13 Solenoid a
14 Dimensions for removal of plug
15 Provision for fitting of an orifice (M8 x 1 spherical)
16 Changeover valve size 10

LFA 50 GSA 50/..



LFA 50 GSB 50/..



COVER WITH BUILT-IN CHANGEOVER VALVE, FOR FITTING A DIRECTIONAL POPPET VALVE: Dimensions in Millimeters RA 81062

LFA 50		50 /			*

Normally closed = GSA
(with directional poppet valve M 3 SE 10U2X/..)
Normally open = GSB
(with directional poppet valve M 3 SE 10C2X/..)

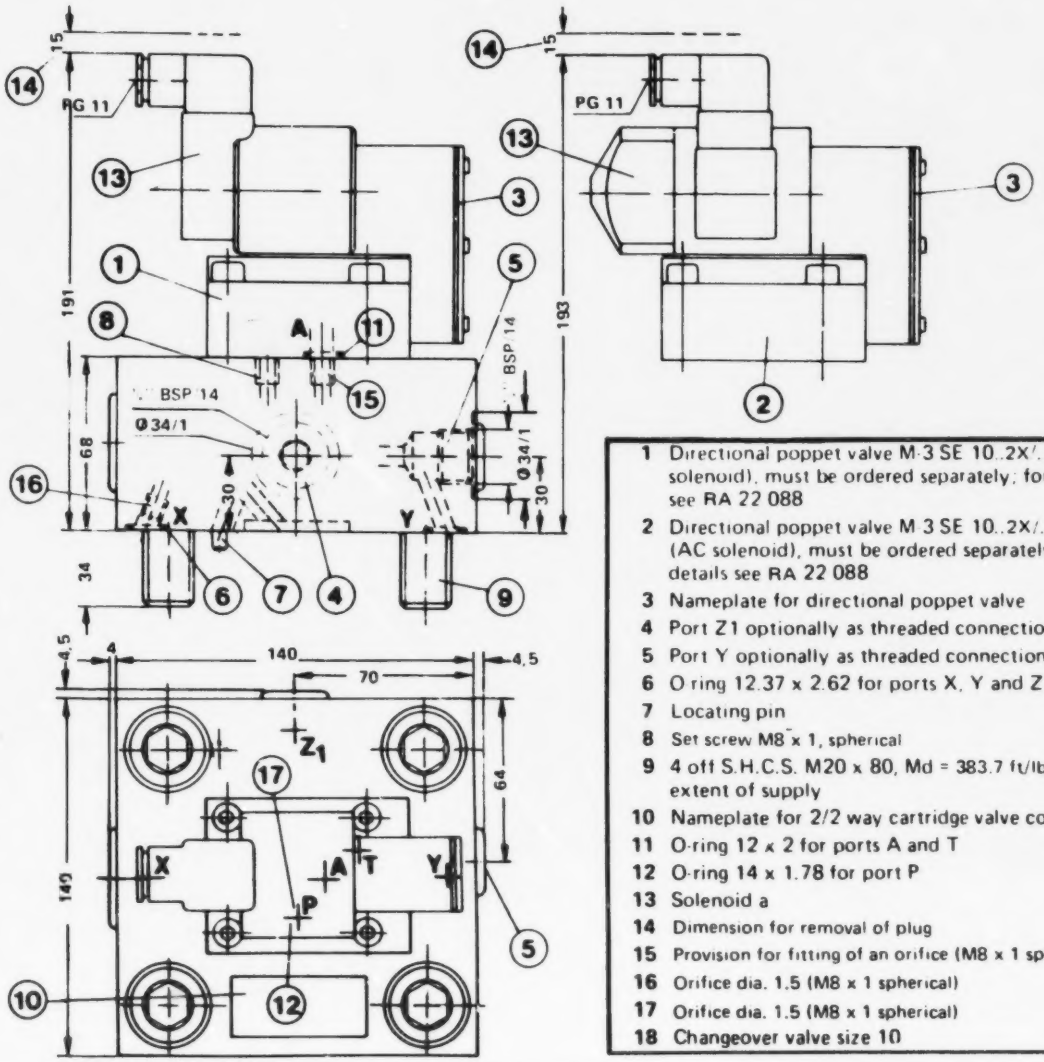
For directional poppet valve, 4500 PSI model = no desig.
For directional poppet valve, 9000 PSI model = 630

Without orifice = no desig.
Orifice in line A + orifice dia. * = A

Further details to be stated in text

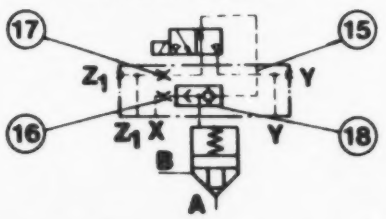
no desig. = Petroleum based hydraulic fluids
V = phosphate ester

*Orifice dia. in 1/10 mm,
e.g. .../A12 = orifice dia. 1.2 mm

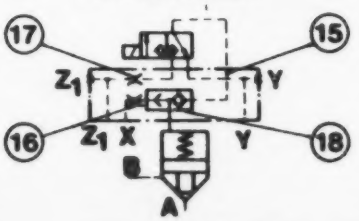


1 Directional poppet valve M 3 SE 10..2X/..G24..Z4.. (DC solenoid), must be ordered separately; for further details see RA 22 088
2 Directional poppet valve M 3 SE 10..2X/..W120-60..Z4 (AC solenoid), must be ordered separately, for further details see RA 22 088
3 Nameplate for directional poppet valve
4 Port Z1 optionally as threaded connection
5 Port Y optionally as threaded connection
6 O ring 12.37 x 2.62 for ports X, Y and Z1
7 Locating pin
8 Set screw M8 x 1, spherical
9 4 off S.H.C.S. M20 x 80, Md = 383.7 ft/lbs, included in extent of supply
10 Nameplate for 2/2 way cartridge valve cover
11 O-ring 12 x 2 for ports A and T
12 O-ring 14 x 1.78 for port P
13 Solenoid a
14 Dimension for removal of plug
15 Provision for fitting of an orifice (M8 x 1 spherical)
16 Orifice dia. 1.5 (M8 x 1 spherical)
17 Orifice dia. 1.5 (M8 x 1 spherical)
18 Changeover valve size 10

LFA 50 KSA 50/..



LFA 50 KSB 50/..



REXROTH
WORLDWIDE HYDRAULICS
MOBILE HYDRAULICS DIVISION
Wooster Ohio
216/262-2010
INDUSTRIAL HYDRAULICS DIVISION
Bethlehem Pa
215/694 8300

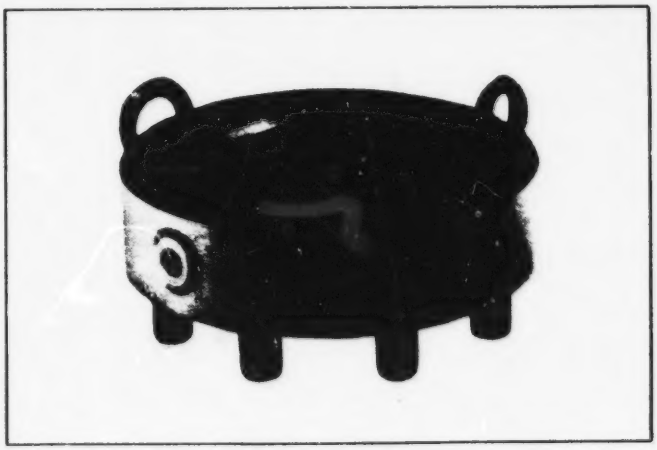
2/2 WAY CARTRIDGE VALVE LC 125
COVER LF 125

RA 81074

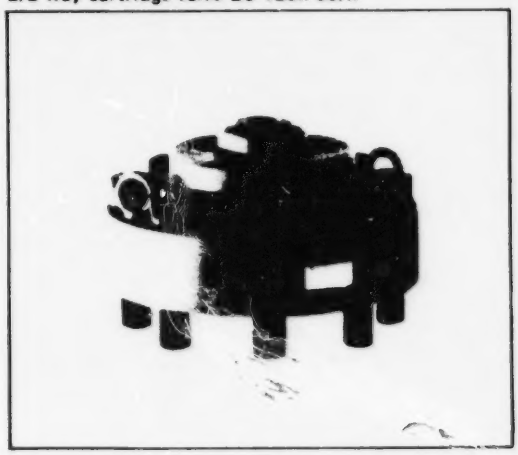
SIZE 125 (5")	UP TO 6000 PSI	UP TO 2640 GPM	ISSUED: 10-82

- Valve poppet with or without cushioning shoulder
- Two area ratios
- Nine possible cracking pressures
- Stroke limiter

2/2 way cartridge valve LC 125..-50/..



Standard cover LF 125 D 20



Cover with stroke limiter: H2

2/2 way cartridge valves comprise mainly a cover (1) and a cartridge assembly (2).

The cartridge assembly is comprised of a sleeve (3), a valve poppet (4), optionally with cushioning shoulder (5) or without cushioning shoulder (6), also a closing spring (7).

Function

2 2 way cartridge valves are purely pressure related. There are therefore three important function surfaces: A1, A2 and A3.

The surface at the valve poppet A1 is regarded as being 100%.

The annulus area A2 is, at area ratio 2:1, 50% of surface A1, and at area ratio 14.3:1, 7% of the surface A1.

Surface A3 = the sum of surfaces A1 and A2. It is always of equal size.

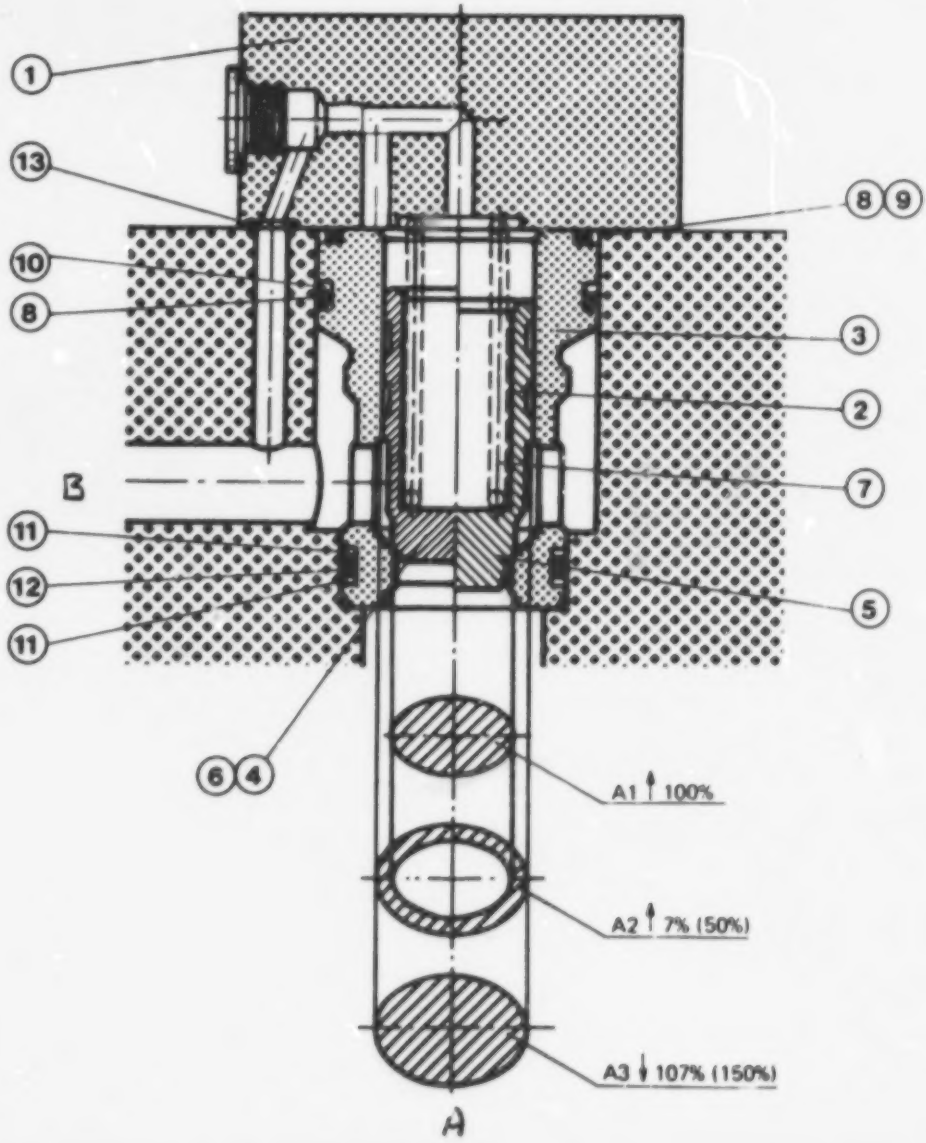
Because of the different area ratios A1:A2 and the different annulus areas (A2) resulting from this, surface A3 is either 107% or 150% of the surface A1 (100%).

Oil can flow through 2/2 way cartridge valves from A to B or from B to A.

Port A is closed leakfree when surface A3 is pressurized by pilot oil taken from port B or external pilot oil supply.

The control of the valve poppet is related to the built-on cover and the control bores in the block.

The 2/2 way cartridge valve opens when, corresponding to the direction of flow, the force affecting surfaces A1 or A2 is greater than the force affecting surface A3.



SEAL ELEMENTS AND SPRINGS: Dimensions in Millimeters

RA 81074

Seal elements

Item	Description	Seal material NBR		Seal material O-rings: Viton Back-up rings: Teflon	
		Dimensions	Part Number	Dimensions	Part number
8	O-Ring	202,56 x 7	002 455	202,56 x 7	001 279
9	Back-up ring	227,8 x 5,9	149 334 (Teflon)	227,8 x 5,9	149 334
10	Back-up ring	209 x 6	143 779 (Teflon)	209 x 6	143 779
11	Back-up ring	184 x 6	143 781 (Teflon)	184 x 6	143 781
12	O-Ring	183,5 x 7	008 042	183,5 x 7	011 195
13	O-Ring	40,87 x 3,53	009 376	40,87 x 3,53	009 505
Seal kit, comprising items 8, 9, 10, 11, 12 and 13		314 060		314 069	

Springs

Cracking pressures at area ratio 2 : 1		14,3 : 1		Type number	Spring dimensions	Part number
6.2 PSI	* 7.2 PSI	4.5 PSI	* 5.0 PSI	05	86/8 x 308/12,5	011 090
12.7 PSI	*14.5 PSI	8.9 PSI	* 10.1 PSI	10	85/9 x 310/10,5	002 649
25.2 PSI	*29.0 PSI	18.1 PSI	* 20.3 PSI	20	83/11 x 310/12,5	002 454
29.7 PSI	*40.6 PSI	21.0 PSI	* 29.0 PSI	30	480/14 x 256/10	002 650

TECHNICAL DETAILS

Hydraulic medium		Petroleum based hydraulic fluids Phosphate ester						
Fluid temperature range		-4...158°F						
Viscosity range		35 to 1750 SSU						
Operating pressure at ports A, B, X, Z1 and Z2	PSI	6000						
		6000						
Cracking pressures at:		Area ratio 2:1				Area ratio 14,3:1			
Flow direction		A → B		B → A		A → B		B → A	
Spring model 00 (effective spool weight)	PSI	2.1		4.3		1.4		21.7	
Spring model 05	PSI	6.2	* 7.2	12.4	*14.5	4.5	* 5.0	63.8	* 72.5
Spring model 10	PSI	12.7	*14.5	25.0	* 29.0	8.9	* 10.1	129.0	*145.0
Spring model 20	PSI	25.2	*29.0	50.7	* 58.0	18.1	* 20.3	259.5	* 290.0
Spring model 30	PSI	29.7	*40.6	58.0	* 81.2	21.0	*29.0	300.1	*406.0
Surface A1	(cm^2)	95				133,7			
Surface A2	(cm^2)	48				9,3			
Surface A3	(cm^2)	143							
Poppet type		with cushioning shoulder (item 5)				without cushioning shoulder (item 6)			
Stroke H	(cm)	4,8				3,8			
Pilot volume	(cm^3)	687				544			
Pilot flow required at a switching time of 10 ms	GPM	1068.50				862.61			
Weight – cartridge assembly	lbs.	70.4							
– standard cover	lbs.	176.0							

For applications to other specifications, please consult us.

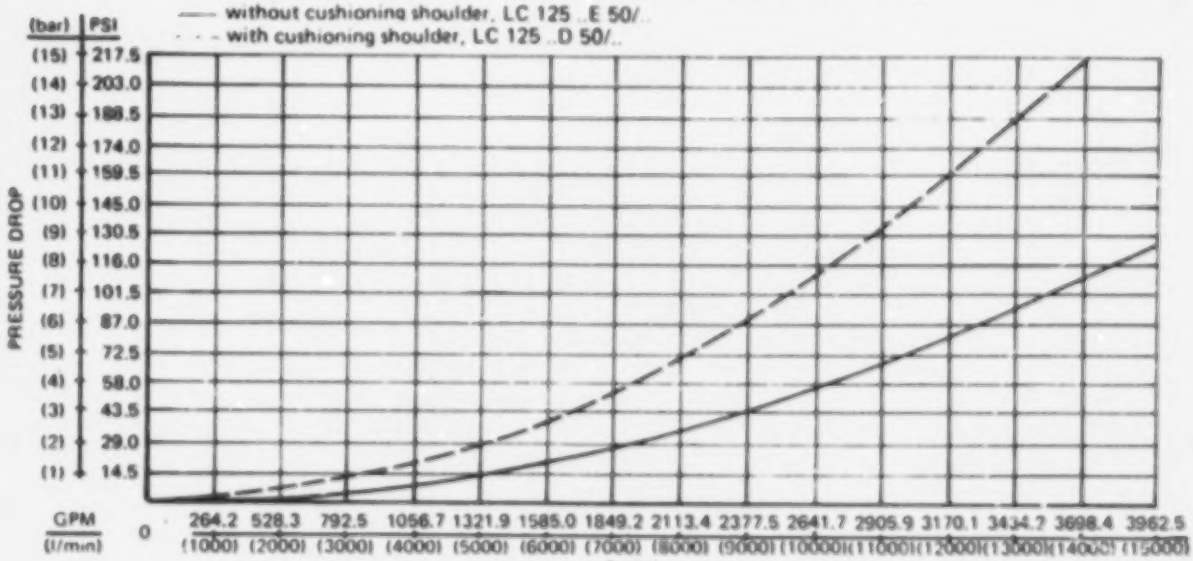
***These cracking pressures are valid for models with stroke limiter H2**

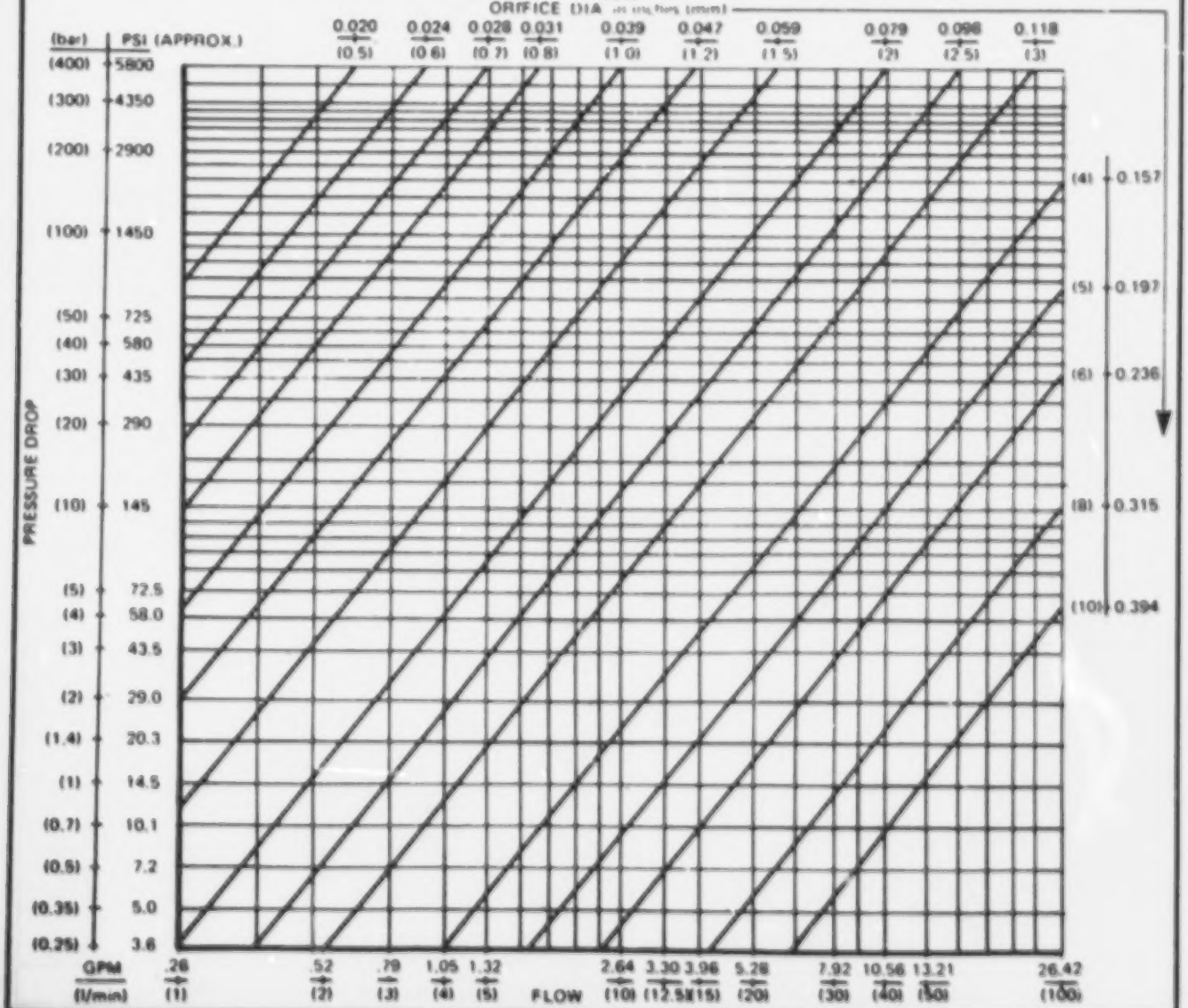
PERFORMANCE CURVES (Measured at v = 167.7 SSU and t = 122°F) RA 81074

p-Q- curves for the 2/2 way cartridge valve without consideration of the spring

—— without cushioning shoulder, LC 125 ..E 50/..

- - - with cushioning shoulder, LC 125 ..D 50/..





ORDERING DETAILS FOR 2/2 WAY CARTRIDGE VALVES

RA 81074

LC125				20	/	*

Area ratio 2:1 (⌀ annulus area = 50%) = A
Area ratio 14.3:1 (⌀ annulus area = 7%) = B

Further details to be stated in text

no desig. = Petroleum based hydraulic fluids
V = phosphate ester

20 = series 20 (20-29 = installation and connection dimensions remain the same)

E = valve poppet without cushioning shoulder
D = valve poppet with cushioning shoulder

Cracking pressures at area ratio 2 : 1		14,3 : 1		
without spring				· 00
6.2 PSI	* 7.2 PSI	4.5 PSI	* 5.0 PSI	· 05
12.7 PSI	* 14.5 PSI	8.9 PSI	* 10.1 PSI	· 10
25.2 PSI	* 29.0 PSI	18.1 PSI	* 20.3 PSI	· 20
29.7 PSI	* 40.6 PSI	21.0 PSI	* 29.0 PSI	· 30

*These cracking pressures are valid for models with stroke limiter H2 and H4

UNIT DIMENSIONS: Dimensions in Millimeters

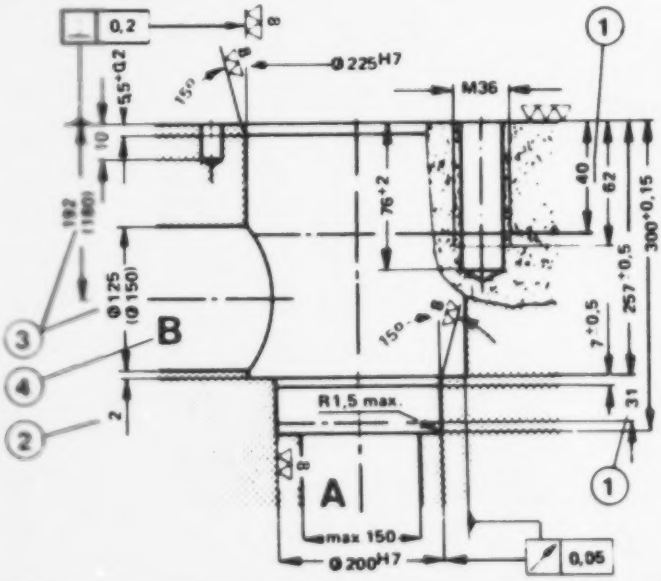
Assembly bore for 2/2 way cartridge valves

1 depth of fit

2 control dimension

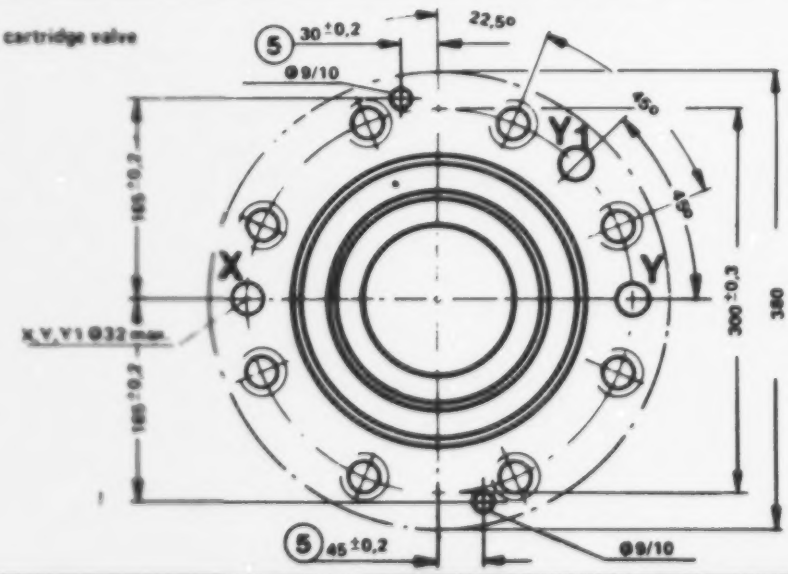
3 If the diameter of Port B is other than 125 or 150, the distance from the cover contact surface to the middle of the bore must be calculated.

4 Port B can be positioned around the center axis of port A. However, care must be taken to avoid damaging the bolt holes and control holes.



Porting pattern for the cover of the 2/2 way cartridge valve

5 Bore for locating pin



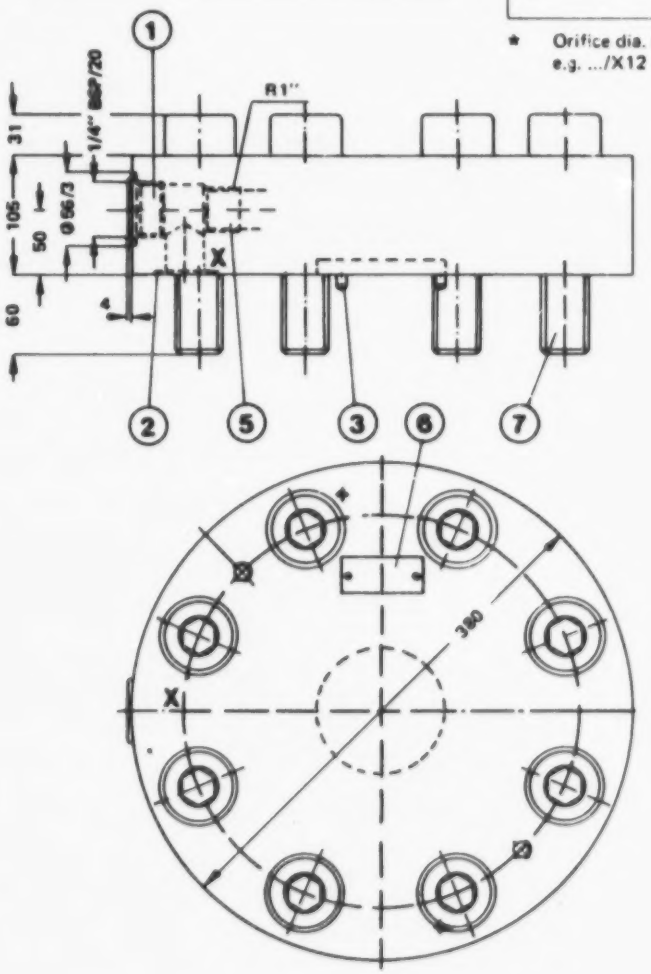
LF 125 D 20 / F [ ] [ ] *

Further details to be stated in text

without orifice	= no desig.
orifice in line X + orifice dia. *	= X ...

no desig.	= Petroleum based hydraulic fluids
V	= phosphate ester

* Orifice dia. in 1/10 mm,
e.g. .../X12 = orifice dia. 1.2 mm



1 Port X optionally as threaded connection

2 O-ring 2–223

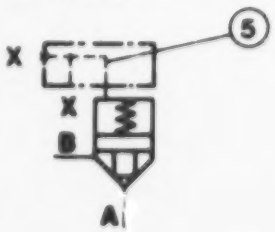
3 Locating pin

5 Provision for fitting of orifice 1" BSP, spherical

6 Nameplate

7 8 off S.H.C.S. M36 x 160
Md = 2287.8 lb-ft, included in extent of supply

LF 125 D 20/ ..



COVER WITH STROKE LIMITER, WITH OR WITHOUT REMOTE CONTROL CONNECTION: Dimensions in Millimeters

RA 81074

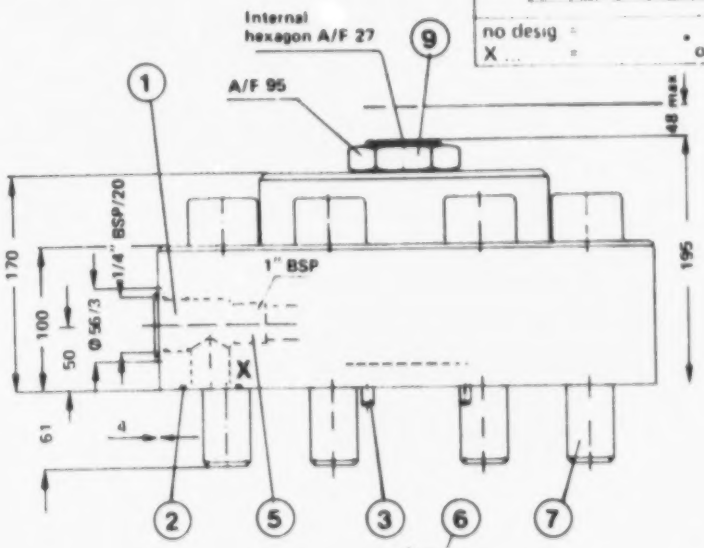
LF 125 H2 -20/F [ ] [ ] *

Further details to be stated in text

no desig = Petroleum based hydraulic fluids
V = phosphate ester

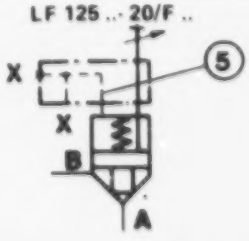
no desig = without orifice
X ... = orifice in line X + orifice dia.

* Orifice dia. in 1/10 mm,
e.g. .../X12 = orifice dia. 1.2 mm



1 Port X optionally as threaded port
2 O-ring 2–223
3 Locating pin
5 Provision for fitting of orifice 1" BSP
6 Nameplate
7 8 off S.H.C.S. M36 x 160, Md = 2287.8 lb-ft, included in extent of supply
9 Stroke limiter with hexagon H2

LF 125 ... 20/F ..



- Valve poppet with or without cushioning shoulder
- Two area ratios
- Nine possible cracking pressures
- Two stroke limiters
- Cover with built-in poppet valve
- Cover with built-in changeover valve
- Cover for fitting directional spool valves with or without built-in changeover valve
- Cover for fitting directional poppet valves with or without built-in changeover valve
- Cover with position control, on request

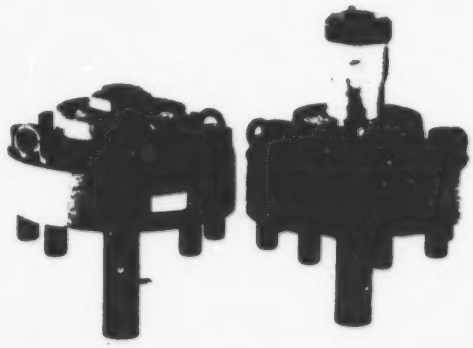
K3314/3

2/2 way cartridge valve LC 100..-50/..

K3320/9

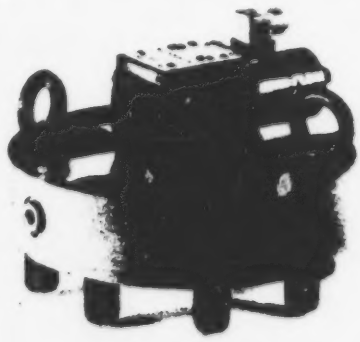
Cover with remote control port LFA 100 D-50/..F..

K3317/10



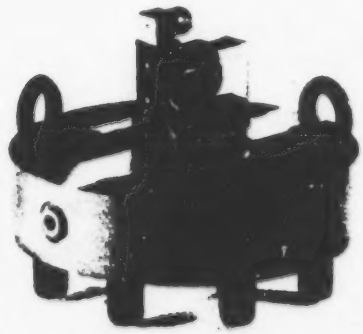
Cover with stroke limiter: H2, H4

K3318/2



Cover with built-on directional spool valve
LFA 100 WE..-50/..

K3319/9



Cover with built-on directional poppet valve
LFA 100 SE..-50/..

Description of Function and Notes on Application

2/2 way cartridge valves comprise mainly a cover (1) and a cartridge assembly (2).

The cover houses the control bores and either a stroke limiter, directional poppet valve or changeover valve, depending on the function required. Directional spool valves or directional poppet valves can be fitted on the cover. The cartridge assembly comprises a bush (3), a valve poppet (4), optionally with cushioning shoulder (5) or without cushioning shoulder (6), also a closing spring (7).

Function

2/2 way cartridge valves are purely pressure related. There are therefore three important function surfaces: A1, A2 and A3.

The surface at the valve poppet A1 is regarded as being 100%.

The annulus area A2 is, at area ratio 2:1, 50% of surface A1, and at area ratio 14.3:1, 7% of the surface A1.

Surface A3 = the sum of surfaces A1 and A2. It is always of equal size.

Because of the different area ratios A1:A2 and the different annulus areas (A2) resulting from this, surface A3 is either 107% or 150% of the surface A1 (100%).

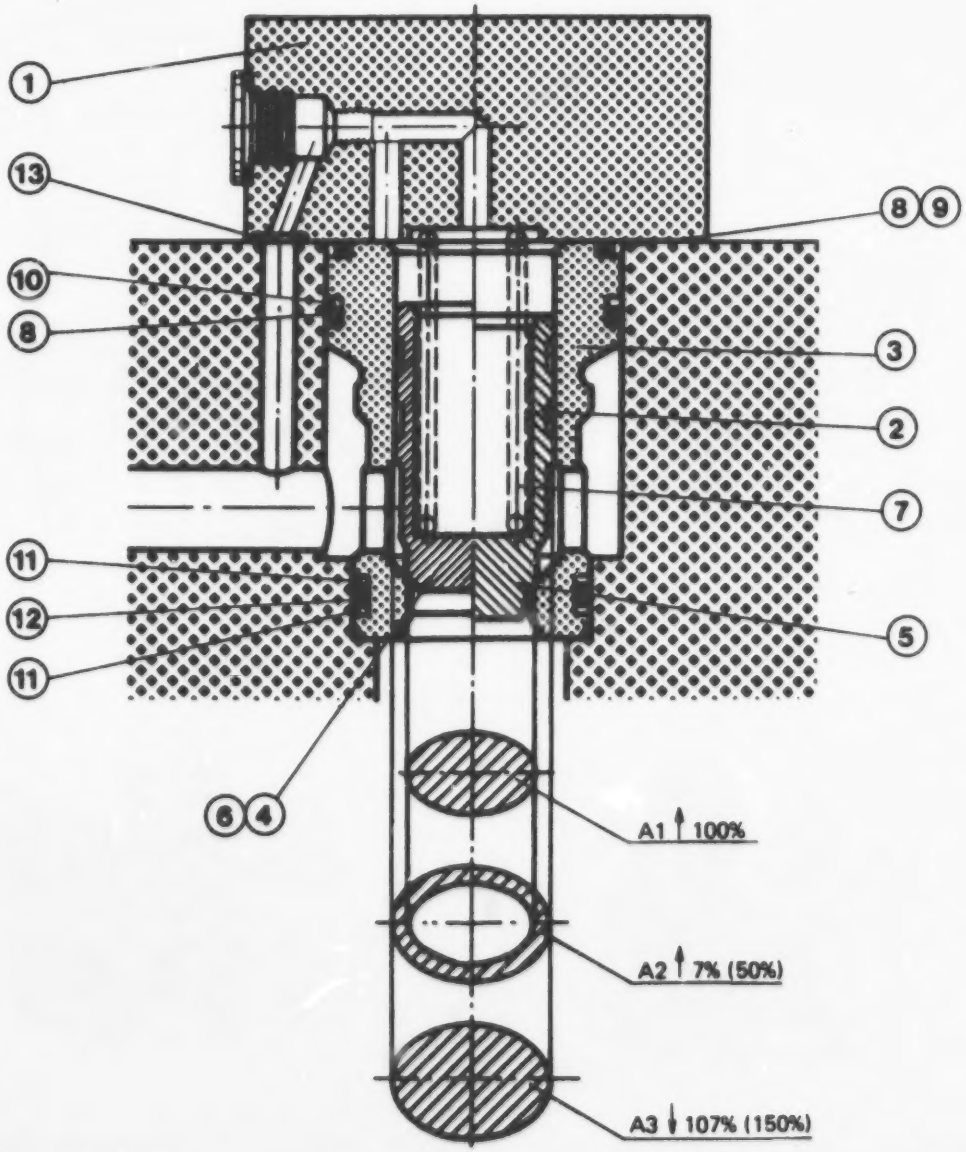
Oil can flow through 2/2 way cartridge valves from A to B or from B to A.

Line A is closed leakfree when surface A3 is pressurised by pilot oil taken from line B or external pilot oil supply.

The control of the valve poppet is related to the built-on cover and the control bores in the block.

The following is generally valid:

The 2/2 way cartridge valve opens when, corresponding to the direction of flow, the force affecting surfaces A1 or A2 is greater than the force affecting surface A3.



Seal Elements and Springs

Seal elements

Item	Description	Seal material NBR		Seal material O-rings: Viton Backing rings: Teflon	
		Dimensions	Part Number	Dimensions	Part Number
8	O-Ring	164,46 x 7	009 080	164,46 x 7	002 396
9	Backing ring	182,8 x 5,9	149 333 (Teflon)	182,8 x 5,9	149 333
10	Backing ring	165,71 x 5,99	002 378	164,2 x 176 x 1,5	002 404
11	Backing ring	121,95 x 5,99	001 896	120 x 132 x 2	001 900
12	O-Ring	120 x 7	001 889	120 x 7	001 890
13		34,52 x 3,53	009 354	34,52 x 3,53	009 191
Seal kit, comprising items 8, 9, 10, 11 and 12		314 059		314 068	

Springs

Cracking pressures at area ratio 2 : 1		Cracking pressures at area ratio 14,3 : 1		Type Number	Spring dimensions Material	Part Number
0,43 bar	*0,5 bar	0,31 bar	*0,35 bar	05	74/7 x 250/14	002 363
0,88 bar	*1,0 bar	0,63 bar	*0,70 bar	10	73/8 x 251/12,5	002 364
1,75 bar	*2,0 bar	1,25 bar	*1,40 bar	20	72/9 x 251/10,5	002 366
3,04 bar	*4,0 bar	2,17 bar	*2,80 bar	40	69/11,5 x 222/10	002 367

Technical Details

Hydraulic medium		Mineral oils, DIN 51 524 and 51 525 Phosphate ester						
Fluid temperature range	(°C)	–20 ... +70						
Viscosity range	(cSt)	2,8 ... 380						
Operating pressure at ports A, B, X, Z1 and Z2	(bar)	...315 (cover with built-on directional spool valve; cover with built-on directional poppet valve, "315 bar" model)						
	(bar)	...420 (cover without built-on directional control valves; cover with built-on directional poppet valve, "630 bar" model)						
Operating pressure at port Y	(bar)	≙ tank pressure of the built-on valves						
Cracking pressures at:		Area ratio 2:1				Area ratio 14,3:1			
Flow direction		A → B		B → A		A → B		B → A	
Spring model 00 (effective spool weight)	(bar)	0,1		0,2		0,07		1	
Spring model 05	(bar)	0,43	*0,5	0,88	*1,0	0,31	*0,35	4,60	* 5
Spring model 10	(bar)	0,88	*1,0	1,78	*2,0	0,63	*0,70	9,40	*10
Spring model 20	(bar)	1,75	*2,0	3,54	*4,0	1,25	*1,40	18,70	*20
Spring model 40	(bar)	3,04	*4,0	6,20	*8,0	2,17	*2,80	32,50	*40
Surface A1	(cm^2)	63,6				89,8			
Surface A2	(cm^2)	31,4				5,2			
Surface A3	(cm^2)	95							
Poppet type		with cushioning shoulder (item 5)				without cushioning shoulder (item 6)			
Stroke H	(cm)	3,8				3			
Pilot volume	(cm^3)	361				285			
Pilot flow required at a switching time of 10 ms (l/min)		2165				1710			
Weight –cartridge	(kg)	27							
–standard cover	(kg)	42							

For applications to other specifications, please consult us.

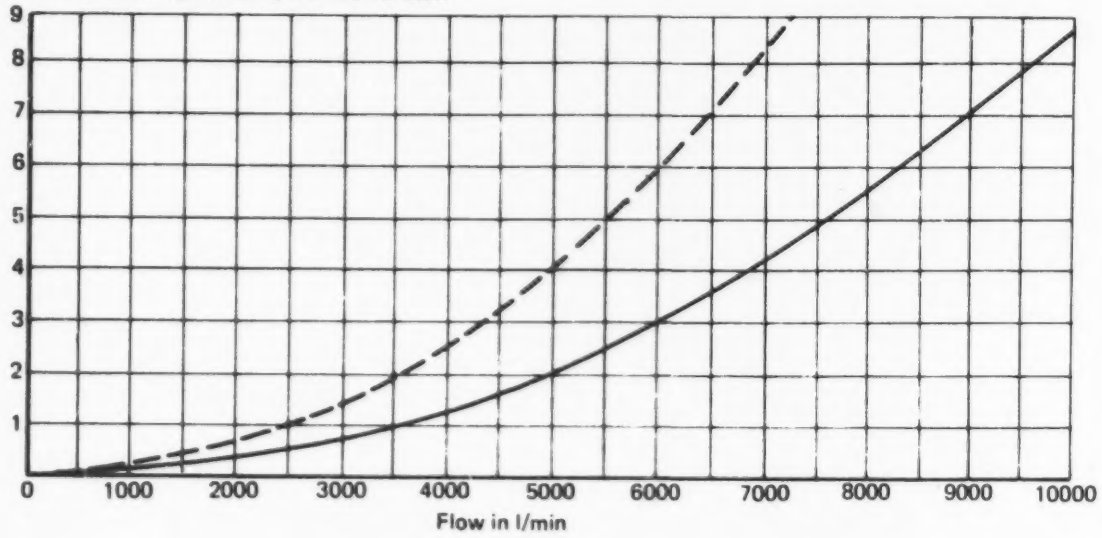
***These cracking pressures are valid for models with stroke limiter H2 and H4.**

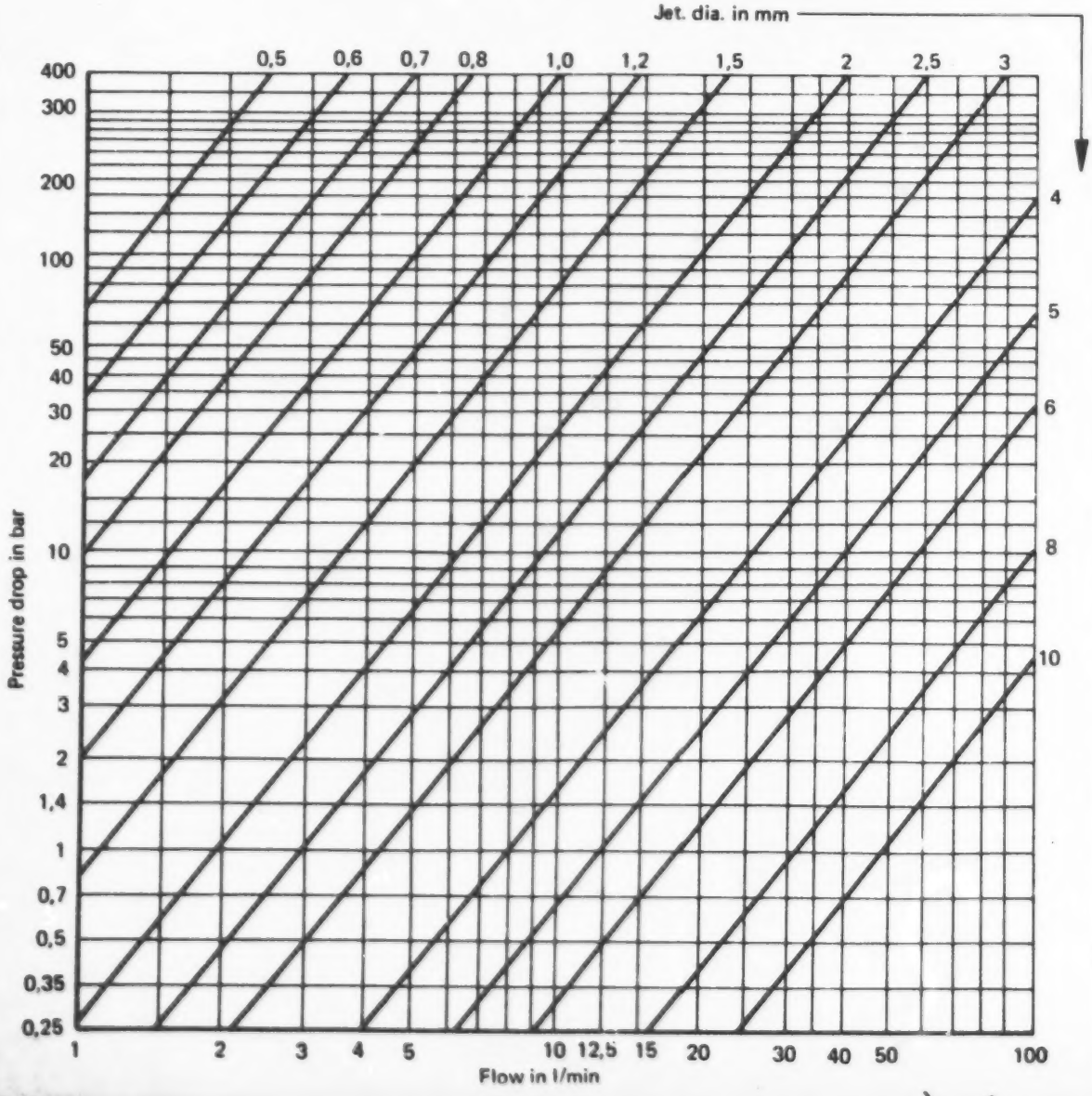
Performance curves (measured at ν = 36 cSt and t = 50° C)

Δp - Q curves for the 2/2 way cartridge valve without consideration of the spring

without cushioning shoulder, LC 100 ..E 50/..

with cushioning shoulder, LC 100 ..D 50/..





R1

Ordering details for 2/2 way cartridge valves

LC 100				50	/	*

Area ratio 2:1 (≙annulus area = 50%) = A
Area ratio 14.3:1 (≙annulus area = 7%) = B

Cracking pressures at area ratio 2 : 1		14,3 : 1		
without spring		–		= 00
0,43 bar	*0,5 bar	0,31 bar	*0,35 bar	= 05
0,88 bar	*1,0 bar	0,63 bar	*0,70 bar	= 10
1,75 bar	*2,0 bar	1,25 bar	*1,40 bar	= 20
3,04 bar	*4,0 bar	2,17 bar	*2,80 bar	= 40

*These cracking pressures are valid for models with stroke limiter H2 and H4.

Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

50 = Series 150
(50 - 59 ≙ installation and connection dimensions remain the same)

E = valve poppet without cushioning shoulder
D = valve poppet with cushioning shoulder

Unit Dimensions

(dimensions in mm)

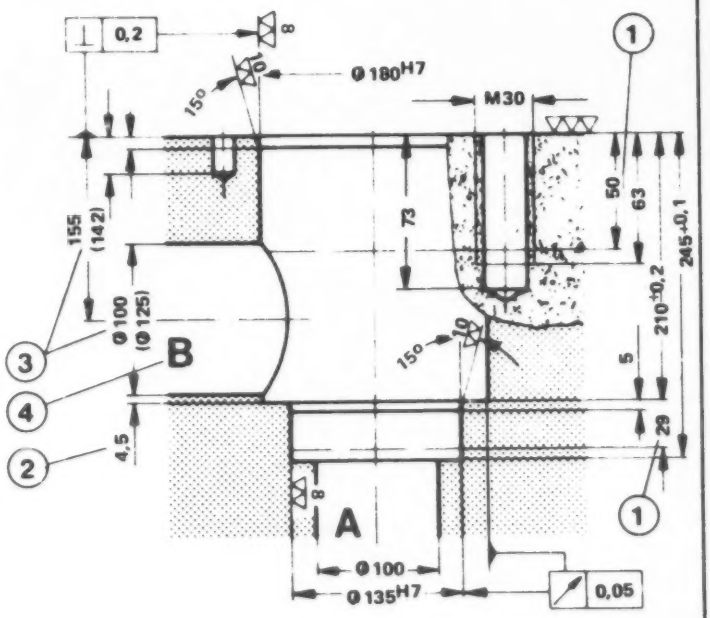
Assembly bore for 2/2 way cartridge valves

1 depth of fit

2 control dimensions

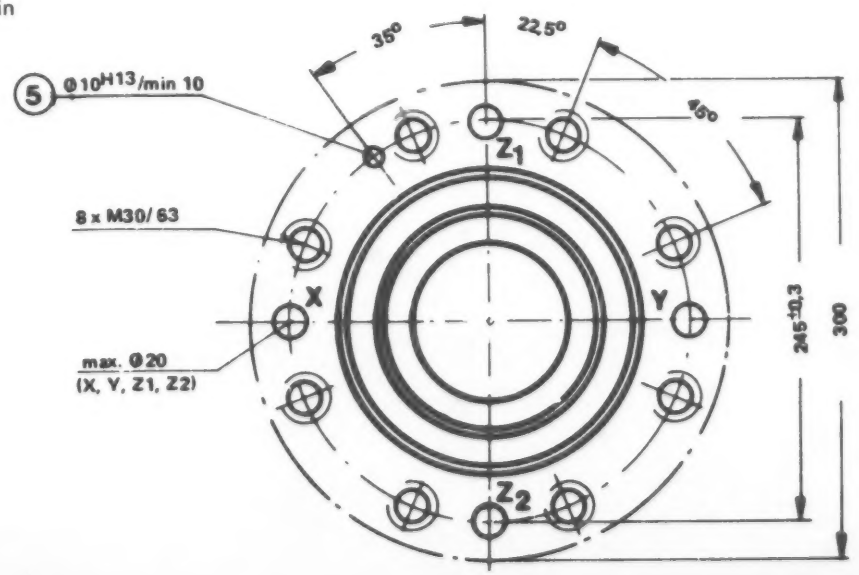
3 If the diameter of port B is other than 100 or 125, the distance from the cover contact surface to the middle of the bore must be calculated.

4 Port B can be positioned around the centre axis of port A. However, care must be taken to avoid damaging the fixing holes and control holes.



Porting pattern for the cover of the 2/2 way cartridge valve

5 Bore for locating pin



B1

Cover with or without remote control connection (dimensions in mm)

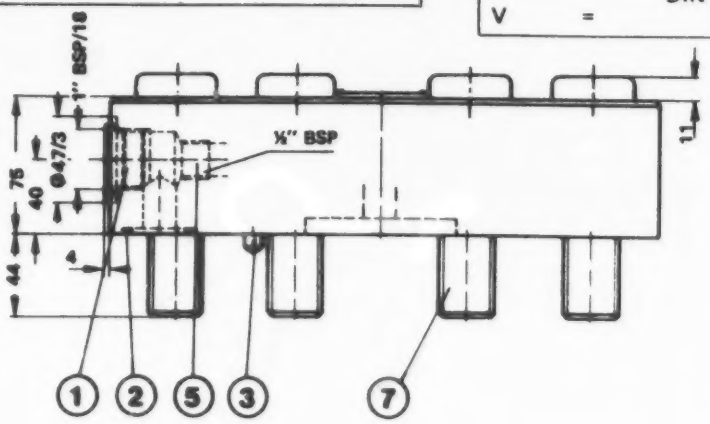
LFA 100 D 50 / F [ ] [ ] [*]

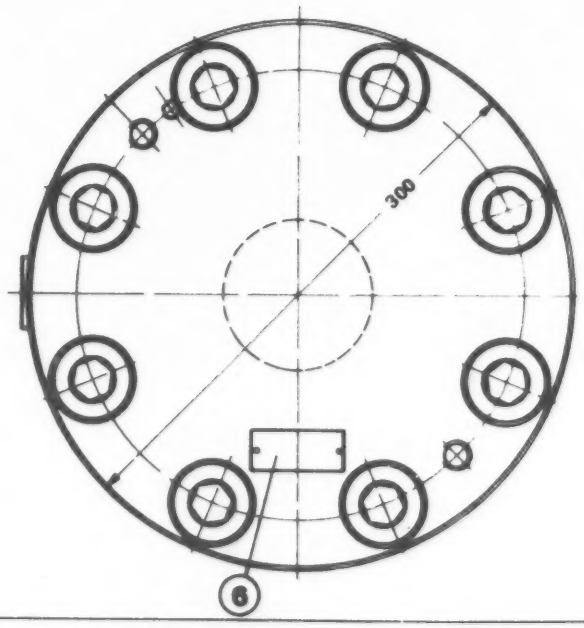
Further details to be stated in text

without jet = no desig.
jet in line X + jet dia. * = X ...

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

*Jet dia. in 1/10 mm, e.g. .../X12 = jet dia. 1.2 mm





1 Port X optionally as threaded connection

2 O-ring 34.52 x 3.53

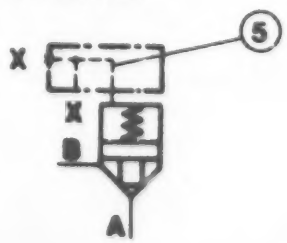
3 Locating pin

5 Provision for fitting of jet (½" BSP)

6 Nameplate

7 8 off S.H.C.S. M30 x 100 Md = 180 da Nm, included in extent of supply

LFA 100 D 50/F..



Cover with Stroke Limiter, with or without Remote Control Connection (dimensions in mm)

LFA 100	– 50 /	F			*

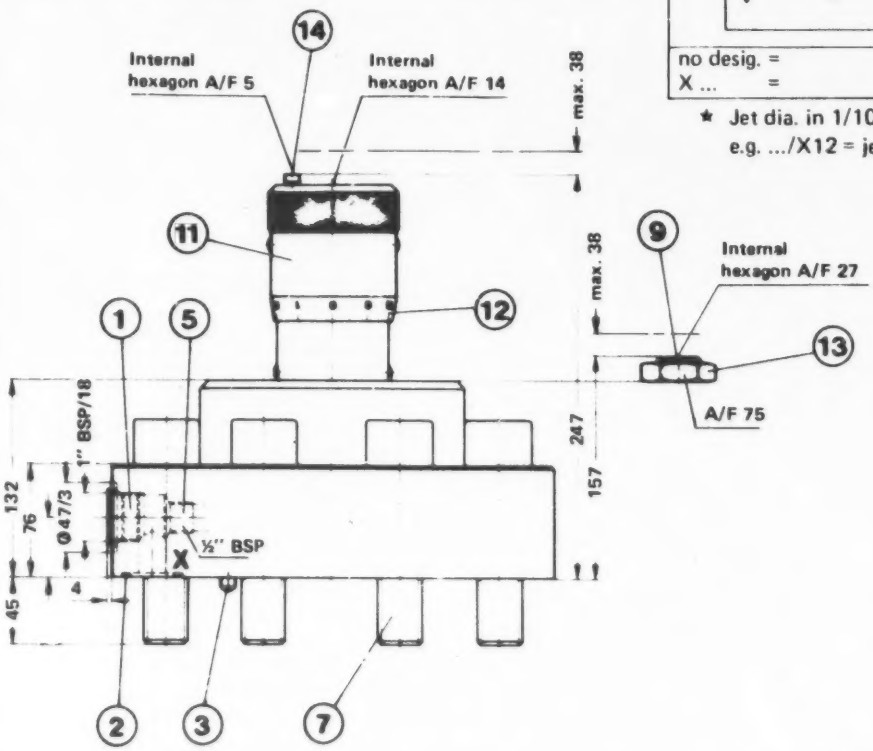
Stroke limiter with hexagon socket = H2
Stroke limiter with scale, not lockable = H4

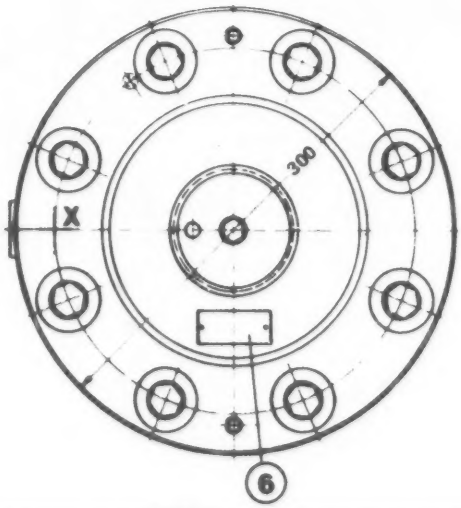
Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

no desig. = without jet
X ... = *jet in line X + jet dia.

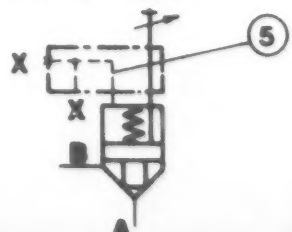
* Jet dia. in 1/10 mm,
e.g. .../X12 = jet dia. 1.2 mm





1 Port X optionally as threaded port
2 O-ring 34.52 x 3.53
3 Locating pin
5 Provision for fitting of jet 1/2" BSP
6 Nameplate
7 8 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply
9 Stroke limiter with hexagon H2
11 Stroke limiter with scale, not lockable, H4
12 Scale
13 Locknut
14 Lock screw

LFA 100 .. - 50/F..

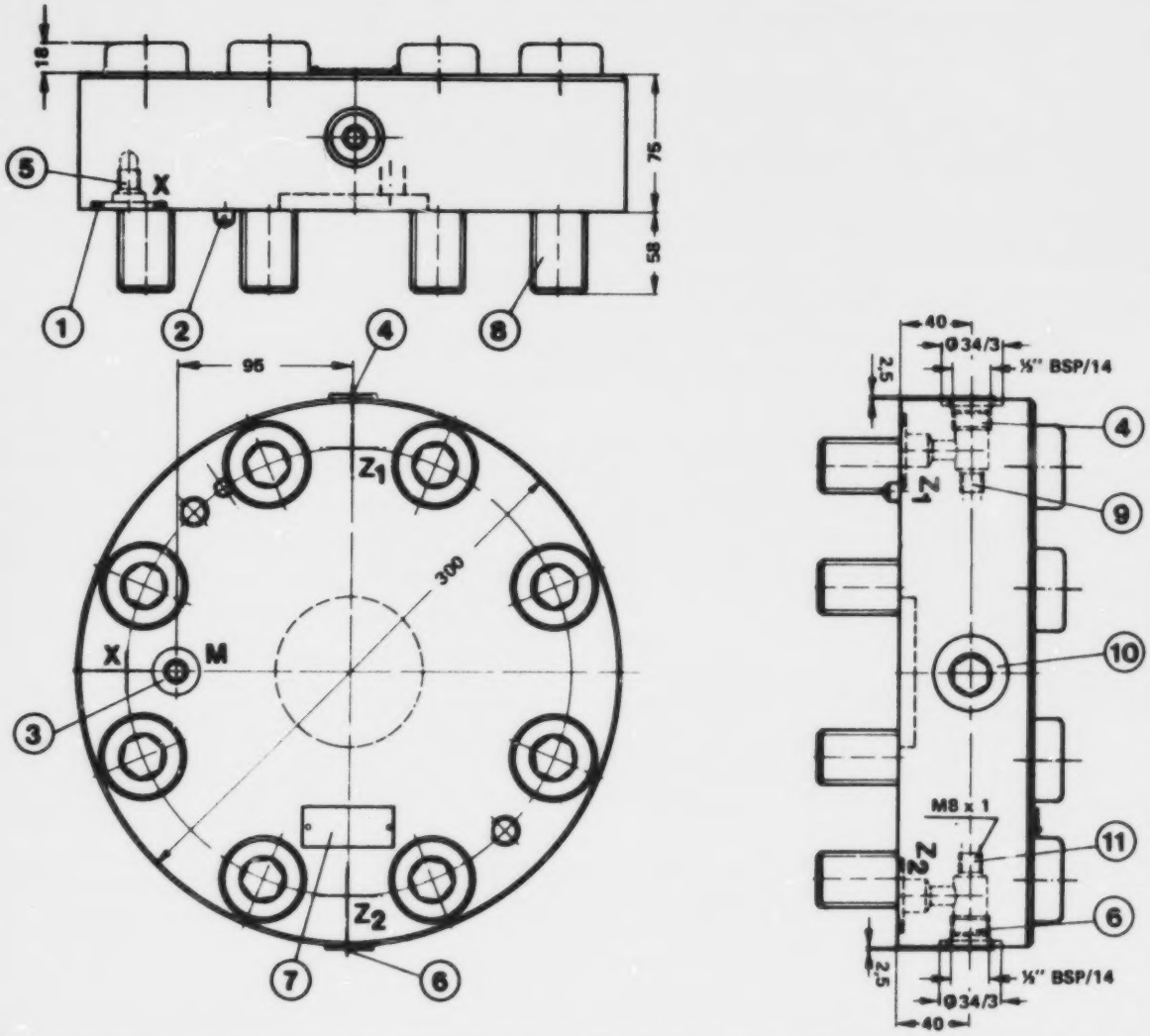


R1

Cover with built-in Changeover Valve (dimensions in mm)

LFA 100 G 50 /	*

Mineral oils DIN 51 524 and 51 525	= no desig.	Further details to be stated in text
Phosphate ester	= V	



1 O-ring 34.52 x 3.53 at ports X, Z1 and Z2

2 Locating pin

3 Measuring port, 1/4" BSP

4 Port Z1, optionally as threaded port

5 Jet, dia. 2.0 (M8 x 1 spherical)

6 Port Z2, optionally as threaded port

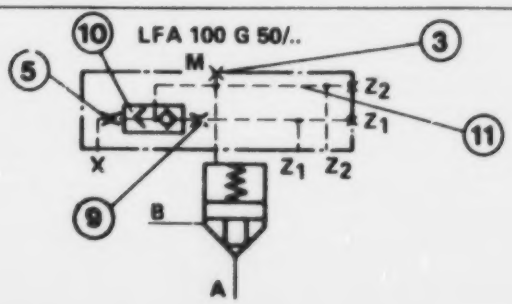
7 Nameplate

8 8 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply

9 Jet, dia. 2.0 (M8 x 1 spherical)

10 Changeover valve size 10

11 Provision for fitting of jet (M8 x 1 spherical)



R1

Cover with built-in Directional Poppet Valve (dimensions in mm)

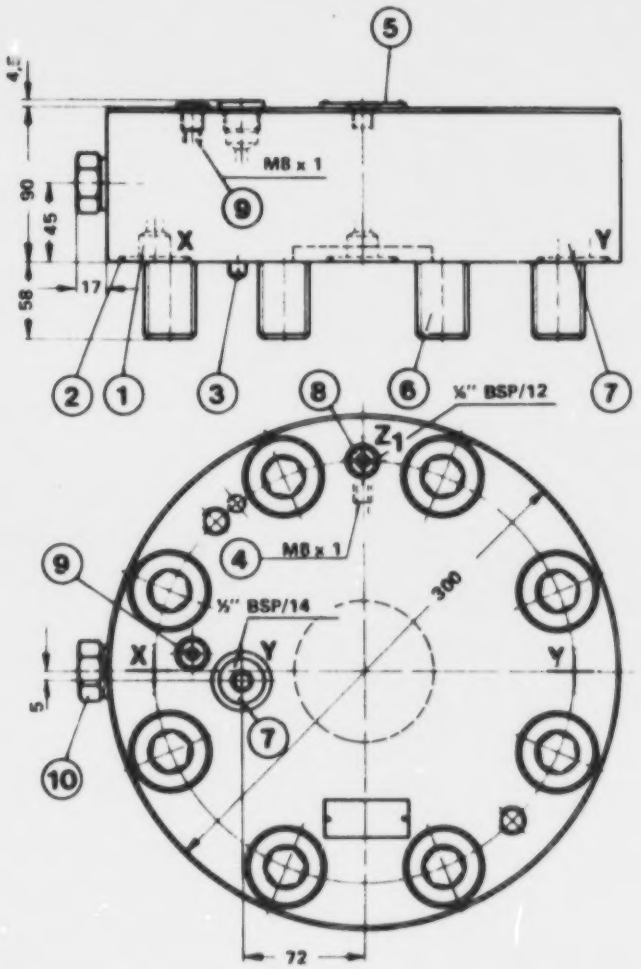
LFA 100 R 50 / ☐ ☐ *

Without jet		= no desig.
Jet in bore to spring chamber F + jet dia.	*	= F ...

Mineral oils DIN 51 524 and 51 525	= no desig.
Phosphate ester	= V

Further details to be stated in text

* Jet dia. in 1/10mm
e.g. .../F12 = jet dia. 1.2 mm



2 O-ring 34.52 x 3.53 on ports X, Y and Z1

3 Locating pin

4 Jet 1.2 (M8 x 1 spherical)

5 Nameplate

6 4 off S.H.C.S. M30 x 120 Md = 180 da Nm, included in extent of supply

7 Port Y optionally as threaded port

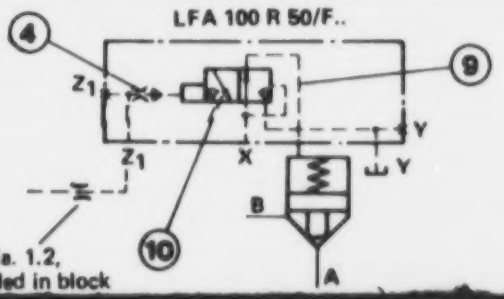
8 Port Z1 optionally as threaded port

9 Provision for fitting a jet (M8 x 1 spherical)

10 Hydraulically operated poppet valve size 10

Area ratio

$$\frac{A_{Z1}}{A_X} = \frac{3}{1}$$



R1

Cover for fitting a Directional Spool Valve (dimensions in mm)

LFA 100		50/		*

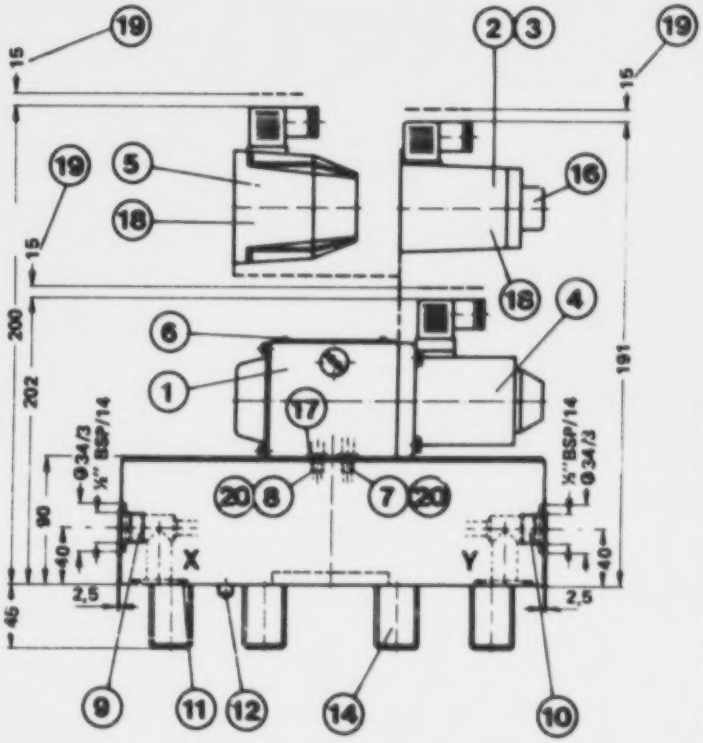
Normally closed (with directional spool valve 4 WE 10 D 10/..) = WEA
Normally open (with directional spool valve 4 WE 10 D 10/..) = WEB

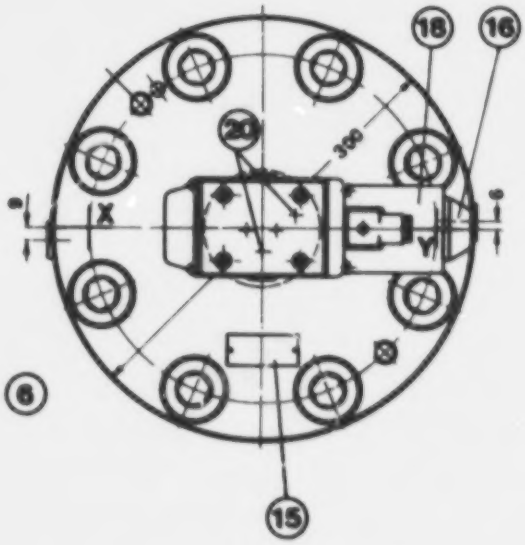
Without jet		= no desig.
Jet in line A + jet dia.	*	= A ...
Jet in line B + jet dia.	*	= B ...
Jet in line P + jet dia.	*	= P ...
Jet in line T + jet dia.	*	= T ...

Further details to be stated in text

no desig.	=	mineral oils DIN 51 524 and 51 525
V	=	phosphate ester

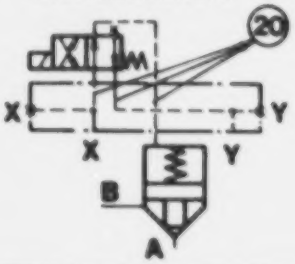
* Jet dia. in 1/10 mm, e.g. .../A12 = jet dia. 1.2 mm



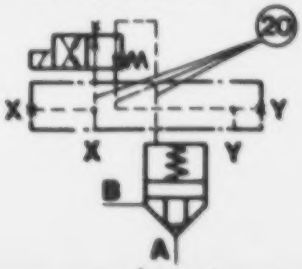


1 Directional valve 4 WE 10 D 10/NZ4.. must be ordered separately
2 DC oil immersed solenoid (RE 23 310)
3 AC oil immersed solenoid (RE 23 312)
4 DC air gap solenoid (RE 23 330)
5 AC air gap solenoid (RE 23 332)
6 Directional valve nameplate
7 Grub screw M8 x 1, spherical, not for type LFA 100 WEA 50/..
8 Grub screw M8 x 1, spherical, not for type LFA 100 WEB 50/..
9 Port X optionally as threaded port
10 Port Y optionally as threaded port
11 O-ring 34.52 x 3.53 at ports X and Y
12 Locating pin
14 4 off S.H.C.S. M30 x 100, Md = 180 da Nm, included in extent of supply
15 Nameplate of 2/2 way cartridge valve cover
16 Hand emergency
17 O-ring 12 x 2 at ports A, B, P and T
18 Solenoid a
19 Dimensions for removal of plug
20 Provision for fitting a jet (M8 x 1 spherical)

LFA 100 WEA 50/..



LFA 100 WEB 50/..



R1

Cover with built-in Changeover Valve, for fitting a Directional Spool Valve (dimensions in mm)

LFA 100		50		*

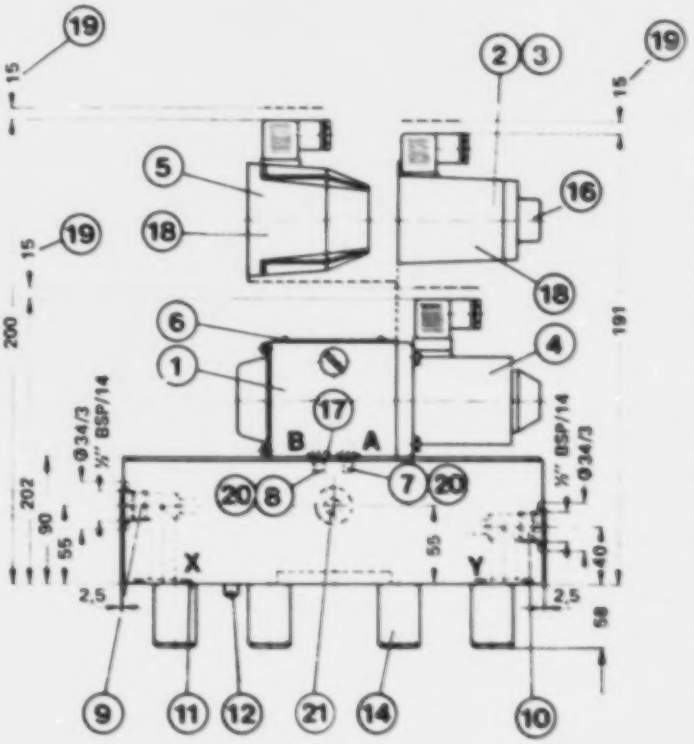
Normally closed (with directional spool valve 4WE10D10/..)	= GWA
Normally open (with directional spool valve 4WE10D10/..)	= GWB

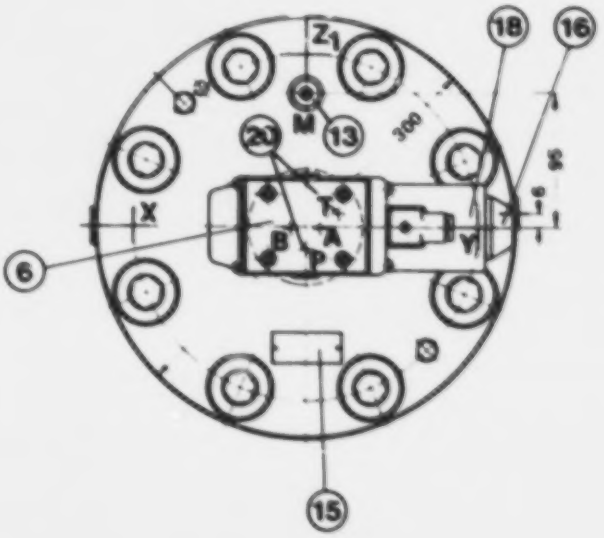
Without jet		= no desig.
Jet in line A + jet dia.	*	= A ...
Jet in line B + jet dia.	*	= B ...
Jet in line P + jet dia.	*	= P ...
Jet in line T + jet dia.	*	= T ...

Further details to be stated in text

no desig. =	mineral oils DIN 51 524 and 51 525
V =	phosphate ester

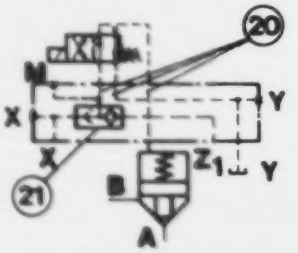
* Jet dia. in 1/10 mm,
e.g. .../A12 = jet dia. 1.2 mm



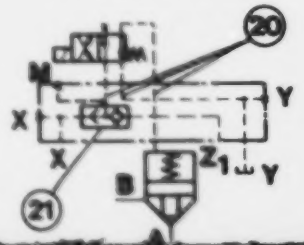


1 Directional valve 4 WE 10 D 10/N24.. must be ordered separately
2 DC oil immersed solenoid (RE 23 310)
3 AC oil immersed solenoid (RE 23 312)
4 DC air gap solenoid (RE 23 330)
5 AC air gap solenoid (RE 23 332)
6 Nameplate of directional valve
7 Grubscrew M8 x 1 spherical, not for type LFA 100 WEA 50/..
8 Grub screw M8 x 1 spherical, not for type LFA 100 WEB 50/..
9 Port X optionally as threaded port
10 Port Y optionally as threaded port
11 O-ring 34.52 x 3.53 at ports X, Y and Z1
12 Locating pin
13 Measuring port M, 1/4" BSP
14 4 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply
15 Nameplate of 2/2 way cartridge valve cover
16 Hand emergency
17 O-ring 12 x 2, at ports A, B, P and T
18 Solenoid a
19 Dimensions for removal of plug
20 Provision for fitting of jet (M8 x 1 sperical)
21 Changeover valve size 10

LFA 100 GWA 50/..



LFA 100 GWB 50/..



R1

Cover with built-in Changeover Valve, for fitting a Directional Spool Valve (dimensions in mm)

LFA 100		50 /		*

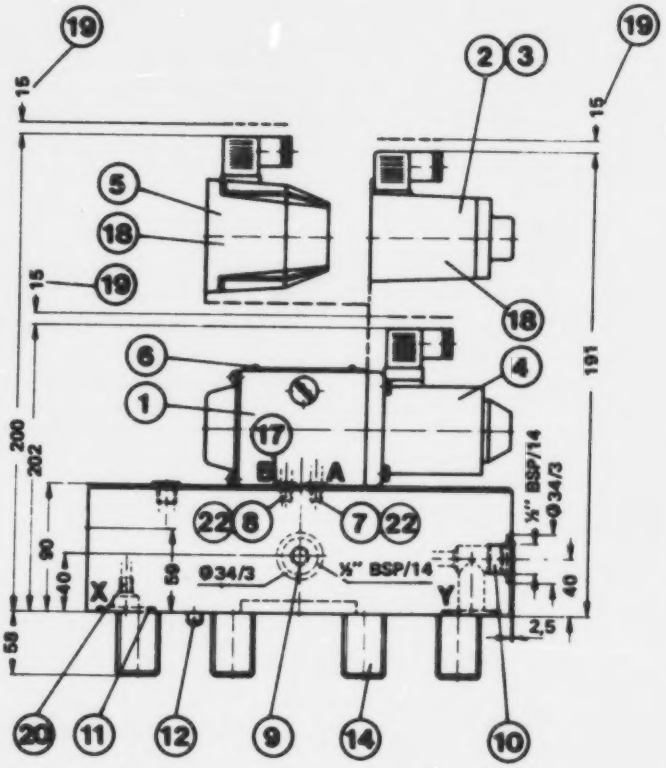
Normally closed = KWA
(with directional spool valve 4WE10D10/..)
Normally open = KWB
(with directional spool valve 4WE10D10/..)

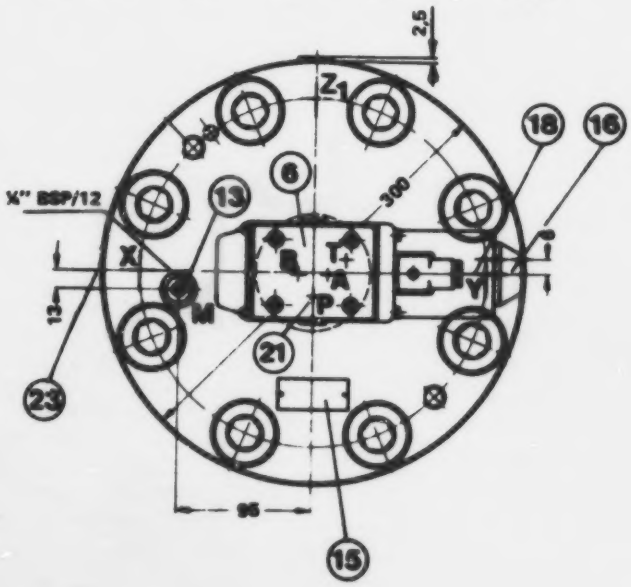
Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

Without jet = no desig.
Jet in line A + jet dia. * = A ...
Jet in line B + jet dia. * = B ...

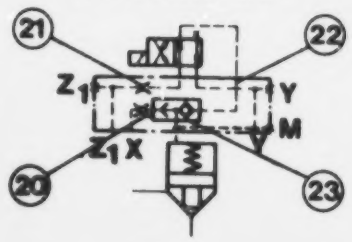
* Jet dia. in 1/10 mm
e.g. .../A12 = jet dia. 1.2 mm



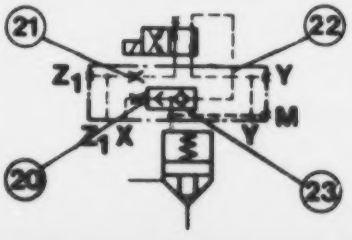


1 Directional valve 4 WE 10 D 10/NZ4.. must be ordered separately
2 DC oil immersed solenoid (RE 23 310)
3 AC oil immersed solenoid (RE 23 312)
4 DC air gap solenoid (RE 23 330)
5 AC air gap solenoid (RE 23 332)
6 Directional valve nameplate
7 Grub screw M8 x 1 spherical, not for type LFA 100 WEA 50/..
8 Grub screw M8 x 1 spherical, not for type LFA 100 WEB 50/..
9 Port Z1 optionally as threaded port
10 Port Y optionally as threaded port
11 O-ring 34.52 x 3.53 for ports X, Y and Z1
12 Locating pin
13 Measuring port M 1/4" BSP
14 4 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply
15 Nameplate of 2/2 way cartridge valve cover
16 Hand emergency
17 O-ring 12 x 2, for ports A, B, P and T
18 Solenoid a
19 Dimension for removal of plug
20 Jet, dia. 2.0 (M8 x-1 spherical)
21 Jet, dia. 2.0 (M8 x 1 spherical)
22 Provision for fitting a jet (M8 x 1 spherical)
23 Changeover valve size 10

LFA 100 KWA 50/..



LFA 100 KWB 50/..



Cover for fitting a Directional Poppet Valve (dimensions in mm)

LFA 100		50/			*

Normally closed = SEA
(with directional poppet valve M-3 SE10U20/..)
Normally open = SEB
(with directional poppet valve M-3 SE10C20/..)

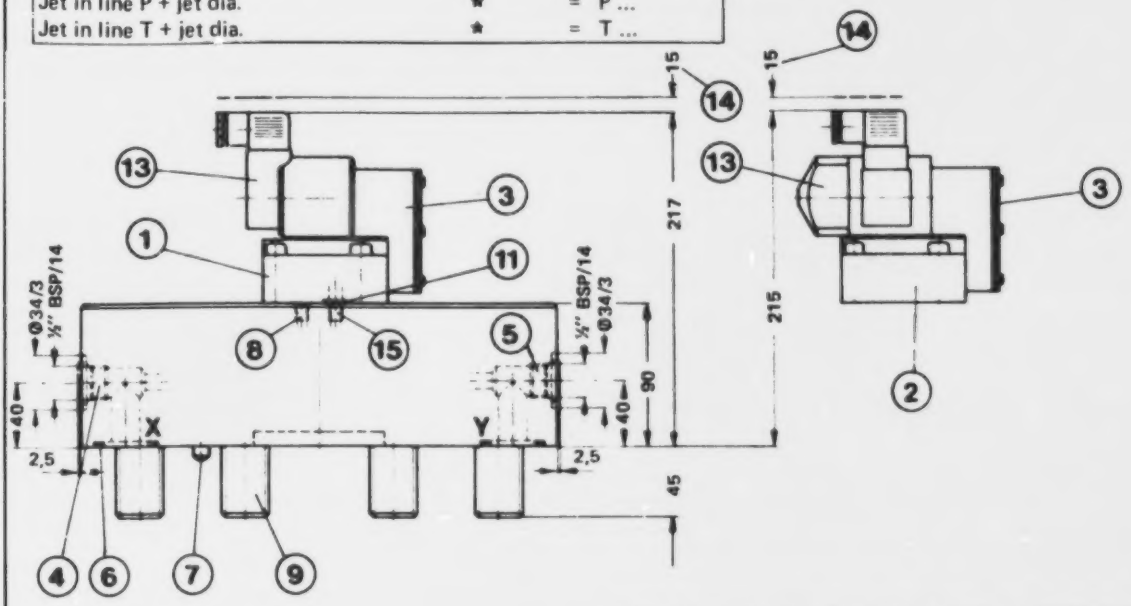
For dir. poppet valve, 315 bar model = no desig.
For dir. poppet valve, 630 bar model = 630

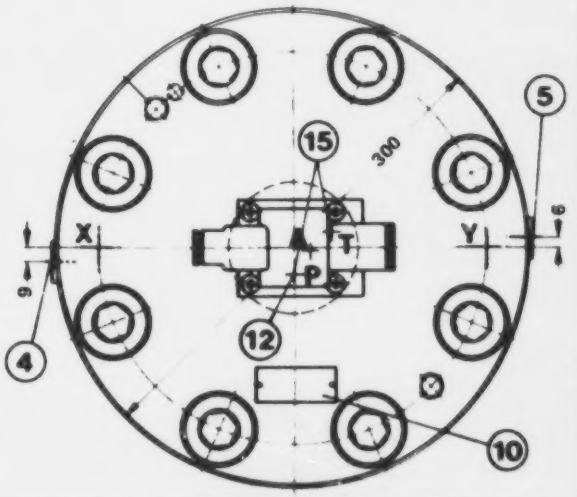
Without jet = no desig.
Jet in line A + jet dia. * = A ...
Jet in line P + jet dia. * = P ...
Jet in line T + jet dia. * = T ...

Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

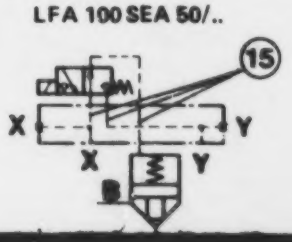
* Jet dia. in 1/10 mm, e.g. .../A12 = jet dia. 1.2 mm



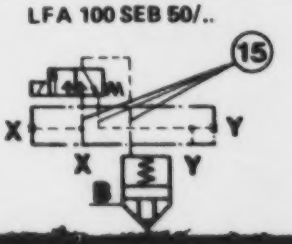


1 Directional poppet valve M-3 SE 10..20/ ..G24..Z4 (DC solenoid), must be ordered separately. For further details, see RE 22 088
2 Directional poppet valve M-3 SE 10..20/ ..W220-50..Z4 (AC solenoid), must be ordered separately. For further details, see RE 22 088
3 Nameplate of directional poppet valve
4 Port X optionally as threaded port
5 Port Y optionally as threaded port
6 O-ring 34.52 x 3.53; at port X and Y
7 Locating pin
8 Grub screw M8 x 1
9 8 off S.H.C.S. M30 x 100, Md = 180 da Nm, included in extent of supply
10 Nameplate of 2/2 way cartridge valve
11 O-ring 12 x 2; at ports A and T
12 O-ring 14 x 1.78; at port P
13 Solenoid a
14 Dimension for removal of plug
15 Provision for fitting a jet (M8 x 1 spherical)

LFA 100 SEA 50/..



LFA 100 SEB 50/..



Cover with built-in Changeover Valve for fitting a Directional Poppet Valve (dimensions in mm)

LFA 100		50				*

Normally closed = GSA
(with directional poppet valve M-3 SE10U20/..)
Normally open = GSB
(with directional poppet valve M-3 SE10C20/..)

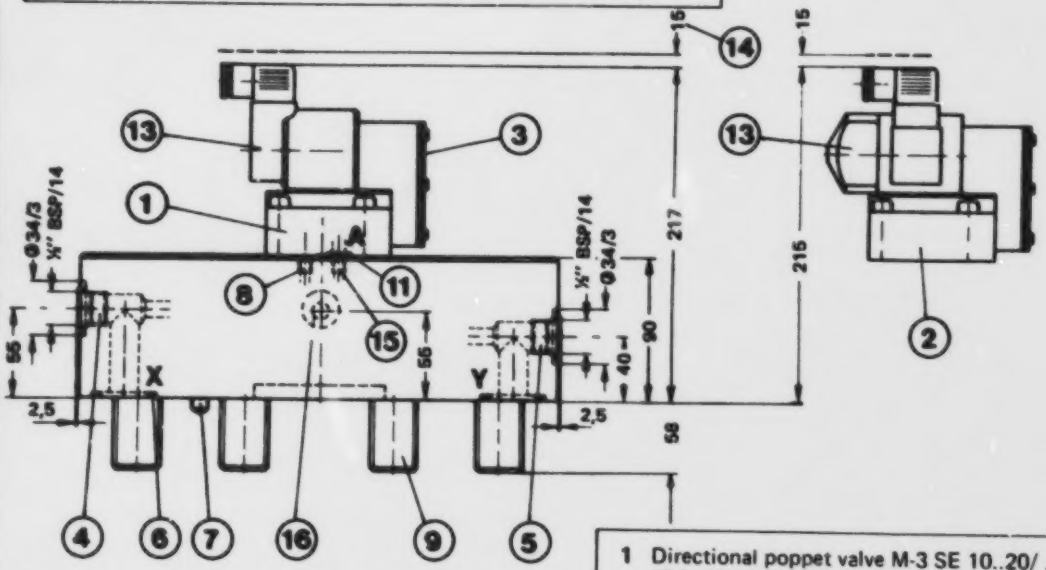
For directional poppet valve, 315 bar model = no desig.
For directional poppet valve, 630 bar model = 630

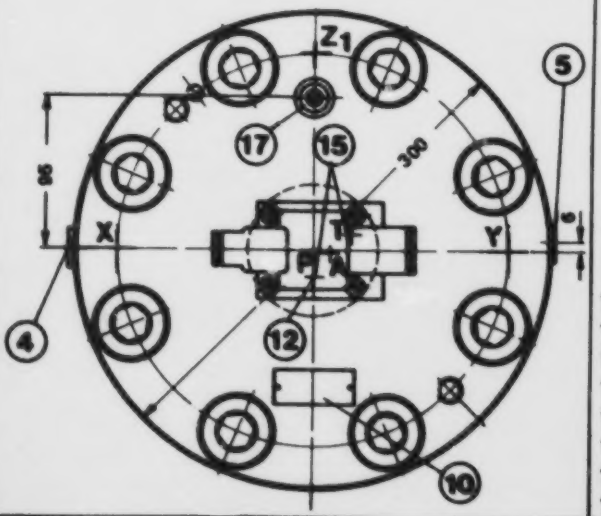
Without jet = no desig.
Jet in line A + jet dia. * = A ...
Jet in line P + jet dia. * = P ...
Jet in line T + jet dia. * = T ...

Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

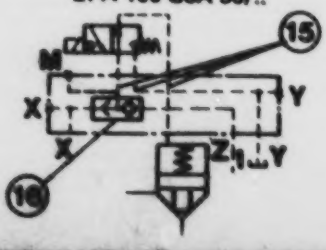
* Jet dia. in 1/10 mm,
e.g. .../A12 = jet dia. 1.2 mm



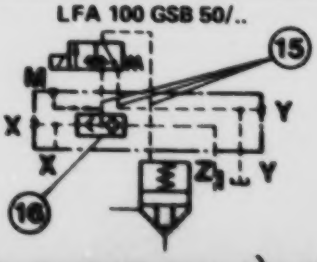


1 Directional poppet valve M-3 SE 10..20/ ..G24..Z4.. (DC solenoid), must be ordered separately; for further details, see RE 22 088
2 Directional poppet valve M-3 SE 10..20/ ..W220-50..Z4.. (AC solenoid), must be ordered separately; for further details, see RE 22 088
3 Nameplate for directional poppet valve
4 Port X optionally as threaded connection
5 Port Y optionally as threaded connection
6 O-ring 34.52 x 3.53 on ports X, Y and Z1
7 Locating pin
8 Grub screw M8 x 1
9 8 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply
10 Nameplate for 2/2 way cartridge valve cover
11 O-ring 12 x 2 for ports A and T
12 O-ring 14 x 1.78 for port P
13 Solenoid a
14 Dimensions for removal of plug
15 Provision for fitting a jet (M8 x 1 spherical)
16 Changeover valve size 10
17 Measuring port M, ¼" BSP

LFA 100 GSA 50/..



LFA 100 GSB 50/..



Cover with built-in Changeover Valve, for fitting a Directional Poppet Valve (dimensions in mm)

LFA 100		50 /				*

Normally closed = KSA
(with directional poppet valve M-3 SE10U20/..)
Normally open
(with directional poppet valve M-3 SE10C20/..) = KSB

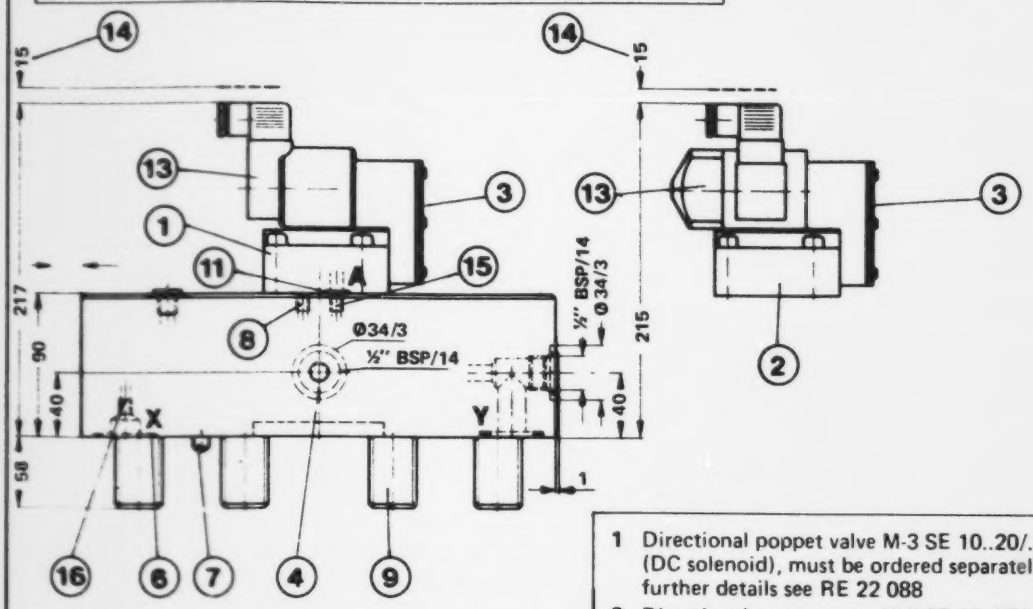
For directional poppet valve, 315 bar model = no desig.
For directional poppet valve, 630 bar model = 630

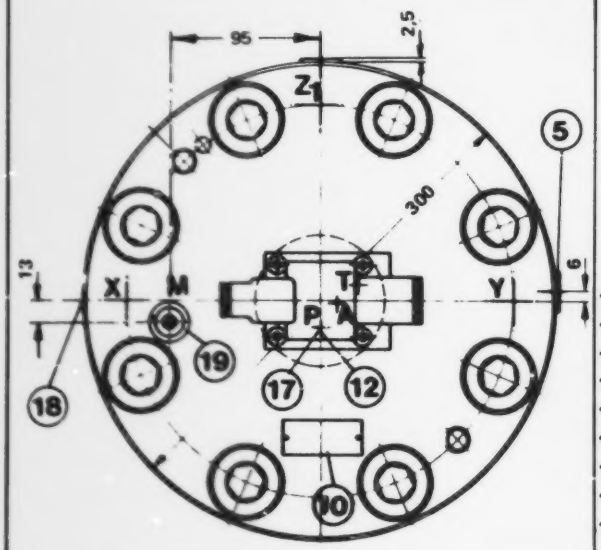
Without jet = no desig.
Jet in line A + jet. dia. ★ = A ...

Further details to be stated in text

no desig. = mineral oils DIN 51 524 and 51 525
V = phosphate ester

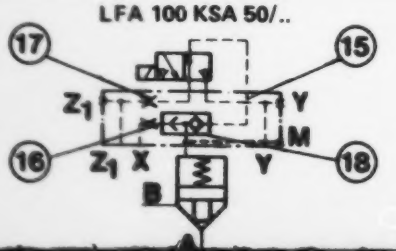
★ Jet dia. in 1/10 mm,
e.g. .../A12 = jet dia. 1.2 mm



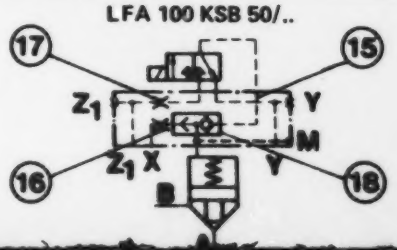


1 Directional poppet valve M-3 SE 10..20/..G24..Z4.. (DC solenoid), must be ordered separately; for further details see RE 22 088
2 Directional poppet valve M-3 SE 10..20/..W220-50..Z4.. (AC solenoid), must be ordered separately; for further details see RE 22 088
3 Nameplate for directional poppet valve
4 Port Z1 optionally as threaded connection
5 Port Z optionally as threaded connection
6 O-ring 34.52 x 3.53 for ports X, Y and Z1
7 Locating pin
8 Grub screw M8 x 1, spherical
9 8 off S.H.C.S. M30 x 120, Md = 180 da Nm, included in extent of supply
10 Nameplate for 2/2 way cartridge valve cover
11 O-ring 12 x 2 for ports A and T
12 O-ring 14 x 1.78 for port P
13 Solenoid a
14 Dimension for removal of plug
15 Provision for fitting a jet (M8 x 1 spherical)
16 Jet. dia. 2.0 (M8 x 1 spherical)
17 Jet. dia. 2.0 (M8 x 1 spherical)
18 Changeover valve size 10
19 Measuring port M, ¼" BSP

LFA 100 KSA 50/..



LFA 100 KSB 50/..



REXROTH
WORLDWIDE HYDRAULICS
MOBILE HYDRAULICS DIVISION
Wooster, Ohio
216/262 2010
INDUSTRIAL HYDRAULICS DIVISION
Bethlehem, Pa
215/694 8300

2/2 WAY CARTRIDGE VALVE LC 16
COVER LFA 16

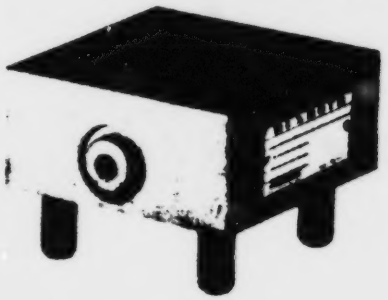
TO DIN 24342

RA 81050

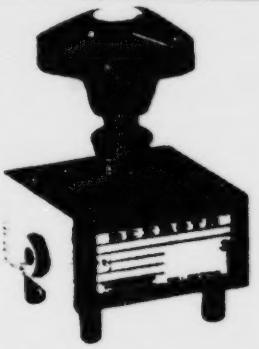
SIZE 16 (3/4")	UP TO 6000 PSI	UP TO 50 GPM	ISSUED 10-81

- Valve poppet with or without cushioning shoulder
- Two area ratios
- Nine possible cracking pressures
- Four stroke limiters
- Cover with built-in changeover valve
- Cover with position control, on request

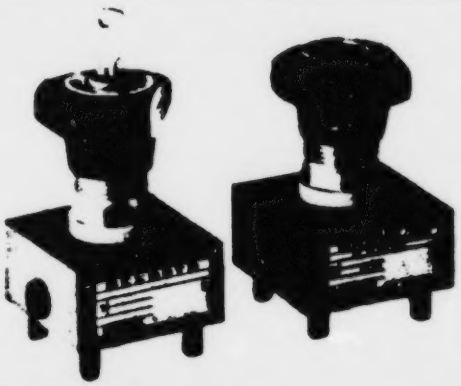
2/2 way cartridge valve LC 16..-50/..



Standard cover LFA 16 D 50/F..



Cover with stroke limiter H1



Cover with stroke limiter: H3, H4

2/2 way cartridge valves comprise mainly a cover (1) and a cartridge assembly (2).

The cover houses the control bores and either a stroke limiter or a changeover valve, depending on the function required.

The cartridge assembly comprises a sleeve (3), a valve poppet (4), optionally with cushioning shoulder (5) or without cushioning shoulder (6), also a closing spring (7) and a ring (14).

Function

2/2 way cartridge valves are purely pressure related. There are therefore three important function surfaces A1, A2 and A3.

The surface at the valve poppet A1 is regarded as being 100%.

The annulus area A2 is, at area ratio 2:1, 50% of surface A1, and at area ratio 14.3:1, 7% of the surface A1.

Surface A3 = the sum of surfaces A1 and A2. It is always of equal size.

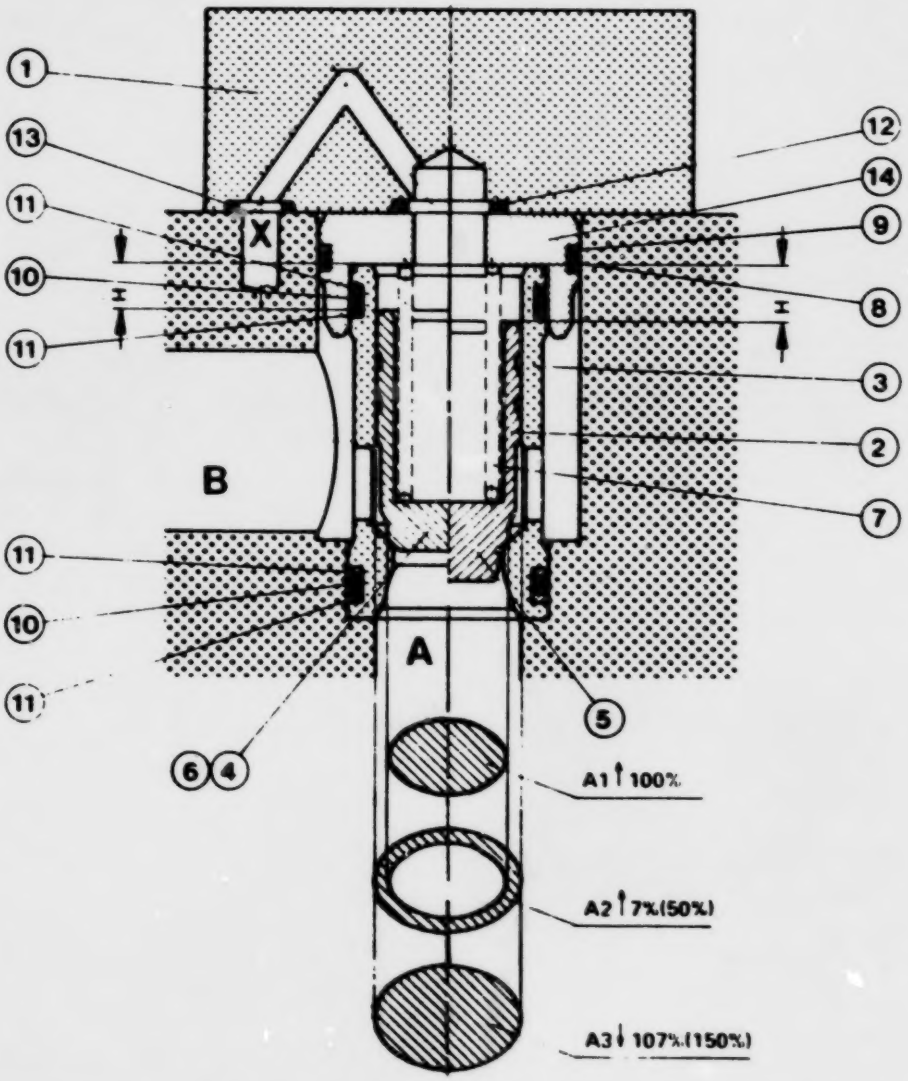
Because of the different area ratios A1:A2 and the different annulus areas (A2) resulting from this, surface A3 is either 107% or 150% of the surface A1 (100%).

Oil can flow through 2/2 way cartridge valves from A to B or from B to A.

Port A is closed leakfree when surface A3 is pressurized by pilot oil taken from Port B or external pilot oil supply.

The control of the valve poppet is related to the built on cover and the control bores in the block.

The 2/2 way cartridge valve opens when, corresponding to the direction of flow, the force affecting surfaces A1 or A2 is greater than the force affecting surface A3.



Seal elements

Item	Description	Seal material NBR Dimensions	Seal material NBR Part number	O-rings Viton Back-up rings: Teflon Dimensions	O-rings Viton Back-up rings: Teflon Part number
8	O-Ring	28,3 x 1,78	001 886	28,3 x 1,78	001 887
9	Back-up ring	29,03 x 1,35	001 899	28 x 30,8 x 1	001 900
10	O-Ring	21,95 x 1,78	001 885	21,95 x 1,78	001 884
11	Back-up ring	21,08 x 1,35	002 142	20,4 x 23 x 1	002 327
12	O-Ring	12,42 x 1,78	009 099	12,42 x 1,78	009 098
13	O-Ring	7,65 x 1,78	004 491	7,65 x 1,78	006 585
Seal kit comprising: items 8, 9, 10, 11, 12 and 13		314 052		314 061	

Springs

Cracking pressures at area ratio 2 : 1	Cracking pressures at area ratio 14,3 : 1	Type number	Spring dimensions	Part number
6.2 PSI	4.4 PSI	05	10,5/0,8 x 42/7	002 110
12.4 PSI	8.9 PSI	10	10,5/1 x 42/8,5	002 111
25.5 PSI	18.4 PSI	20	10,2/1,25 x 42/11	002 112
49.3 PSI	35.5 PSI	40	10/1,4 x 42/9,5	002 113

TECHNICAL DETAILS

Hydraulic medium		Petroleum based hydraulic fluids phosphate ester			
Fluid temperature range		-4...158°F			
Viscosity range		35 to 1750 SSU			
Operating pressure at ports A, B, X, Z1 and Z2	PSI	6000			
Cracking pressures at:		Area ratio 2:1		Area ratio 14,3:1	
Flow direction		A - B	B - A	A - B	B - A
Spring model 00 (effective spool weight)	PSI	0.2	0.5	0.2	3.4
Spring model 05	PSI	6.2	13.0	4.4	72.5
Spring model 10	PSI	12.4	26.1	8.9	145.0
Spring model 20	PSI	25.5	53.6	18.4	298.7
Spring model 40	PSI	49.3	104.4	35.5	580.0
Surface A1	(cm^2)	1,54		2,14	
Surface A2	(cm^2)	0,73		0,13	
Surface A3	(cm^2)	2,27			
Poppet type		with cushioning shoulder (item 5)		without cushioning shoulder (item 6)	
Stroke H	(cm)	0,7		0,7	
Pilot volume	(cm^3)	1,6		1,6	
Pilot flow required at a switching time of 10 ms	GPM	2.53		2.53	
Weight – cartridge assembly	lbs.	0.4			
Weight – standard cover	lbs.	2.6			

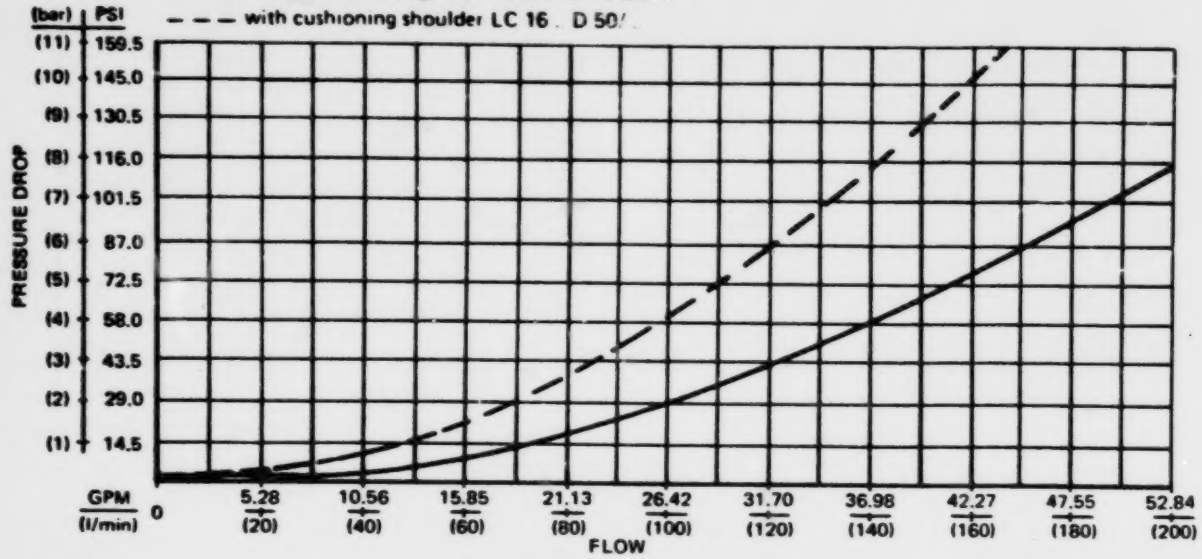
For applications to other specifications, please consult us.

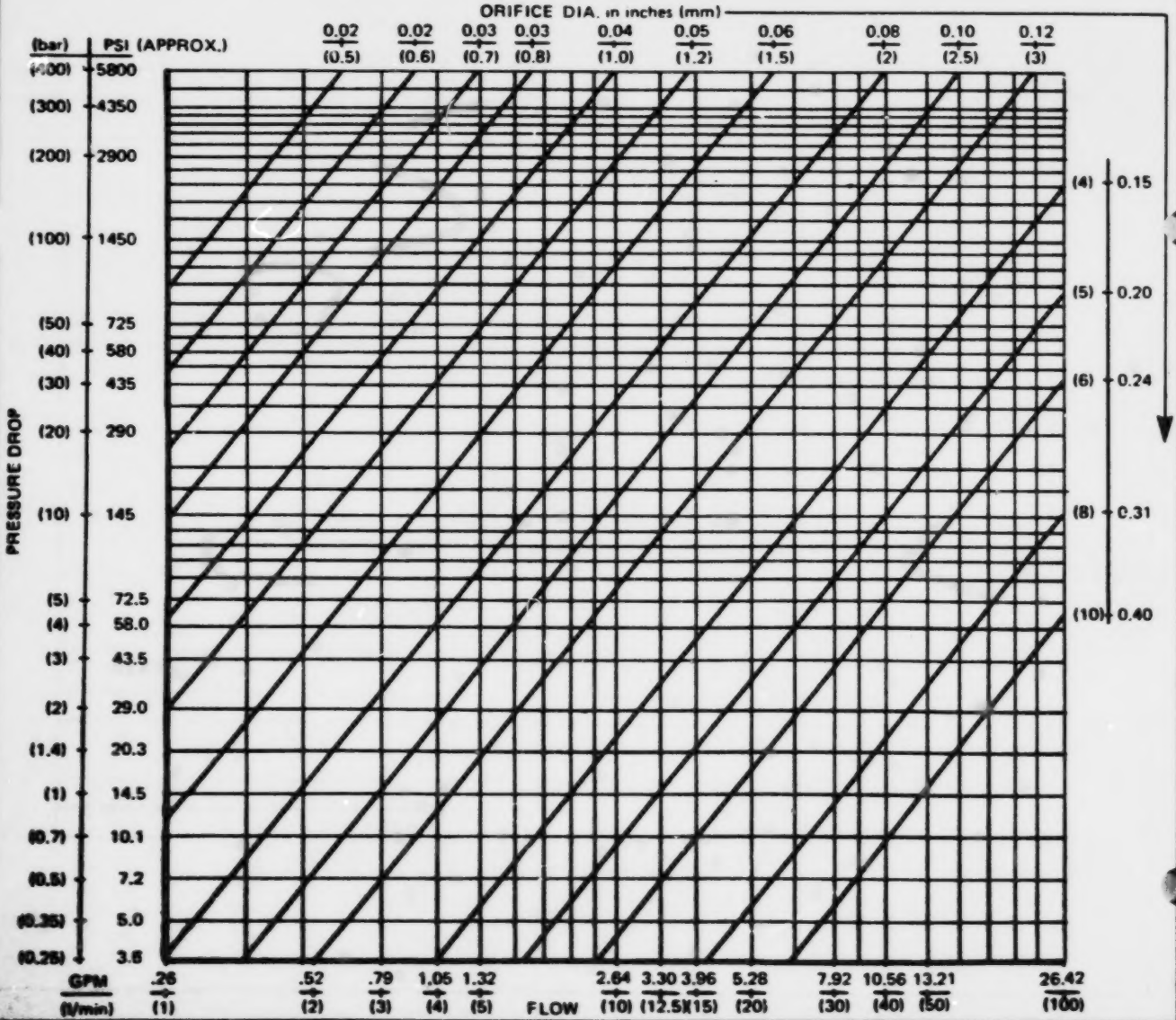
PERFORMANCE CURVES (Measured at ν = 167.7 SSU and t = 122°F) RA 81050

Δp-Q curves for the 2/2 way cartridge valve without consideration of the spring

——— without cushioning shoulder LC 16 . E 50/ ..

– – – with cushioning shoulder LC 16 . D 50/ ..





ORDERING DETAILS FOR 2/2 WAY CARTRIDGE VALVES

RA 81050

LC16				50	/	*

Area ratio 2:1 (≙ annulus area = 50%) = A
Area ratio 14.3:1 (≙ annulus area = 7%) = B

Further details to be stated in text

no designation = Petroleum based hydraulic fluids
V = phosphate ester

50 = Series 50
(50-59 ≙ installation and connection dimensions remain the same)

E = valve poppet without cushioning shoulder
D = valve poppet with cushioning shoulder

Cracking pressures at area ratio 2 : 1	Cracking pressures at area ratio 14,3 : 1	
without spring	-	= 00
6.2 PSI	4.4 PSI	= 05
12.4 PSI	8.9 PSI	= 10
25.5 PSI	18.4 PSI	= 20
49.3 PSI	35.5 PSI	= 40

UNIT DIMENSIONS: Dimensions in Millimeters

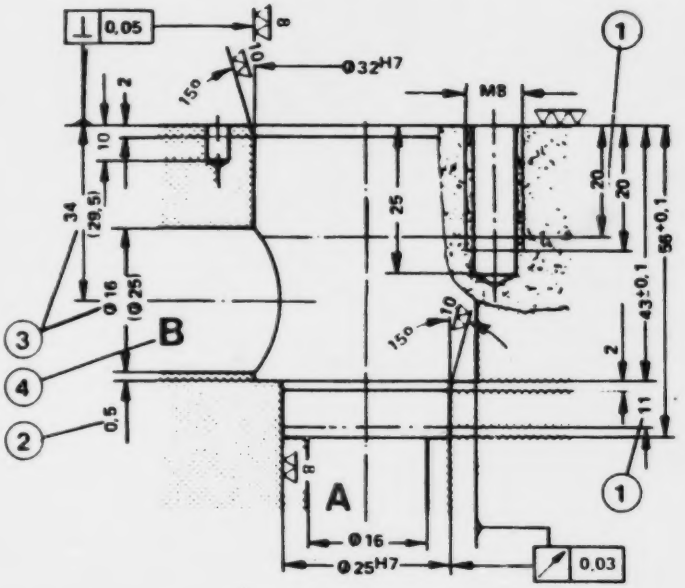
Assembly bore for 2/2 way cartridge valves

1 depth of fit

2 control dimension

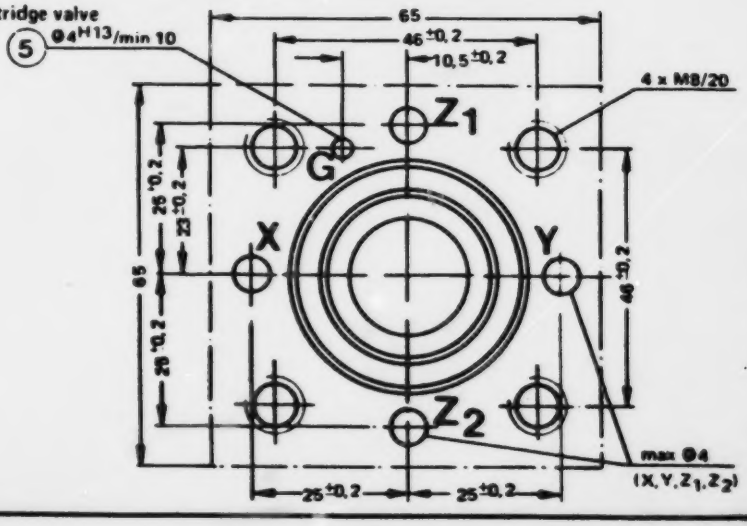
3 If the diameter of port B is other than 16 or 25, the distance from the cover contact surface to the middle of the bore must be calculated

4 Port B can be positioned around the center axis of port A. However, care must be taken to avoid damaging the bolt holes and control holes



Porting pattern for the cover of the 2/2 way cartridge valve

5 Bore for locating pin



LFA 16 D 50 / | | | | *

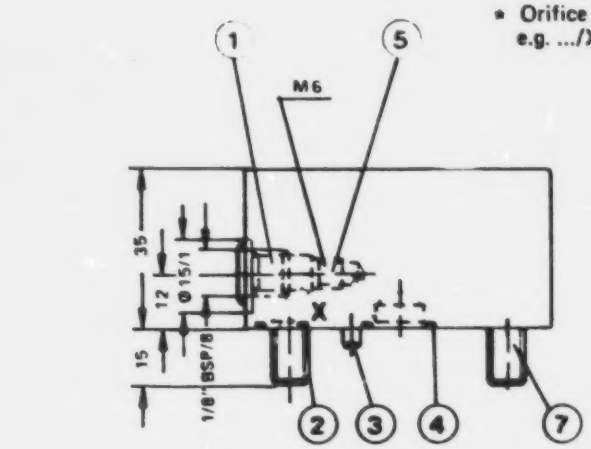
Without remote control port X (only w/o orifice) = no desig.
With remote control port X F

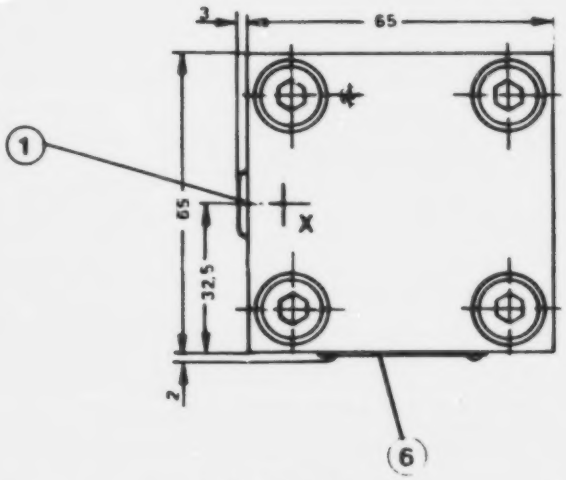
Without orifice no desig
Orifice effective in line X + orifice dia. (for model with remote control port X only) X

Further details to be stated in text

No desig · Petroleum based hydraulic fluids
V · phosphate ester

* Orifice dia. in 1/10 mm,
e.g. .../X 12 ⌀ orifice dia. 1.2 mm





1 Port X optionally as threaded connection on cover model LFA 16 D 50/F..

2 O-ring 7.65 x 1.78

3 Locating pin

4 O-ring 12.42 x 1.78

5 Provision for fitting of orifice M6 (LFA 16../F .. only)

6 Nameplate

7 4 off S H C S M8 x 40
Md = 23.6 ft./lbs., included in extent of supply

LFA 16 D 50/..

LFA 16 D 50/F..

LFA 16	– 50 /				•

Stroke limiter with handwheel = H1
Stroke limiter with hexagon socket = H2
Stroke limiter with scale, lockable = H3
Stroke limiter with scale, not lockable = H4

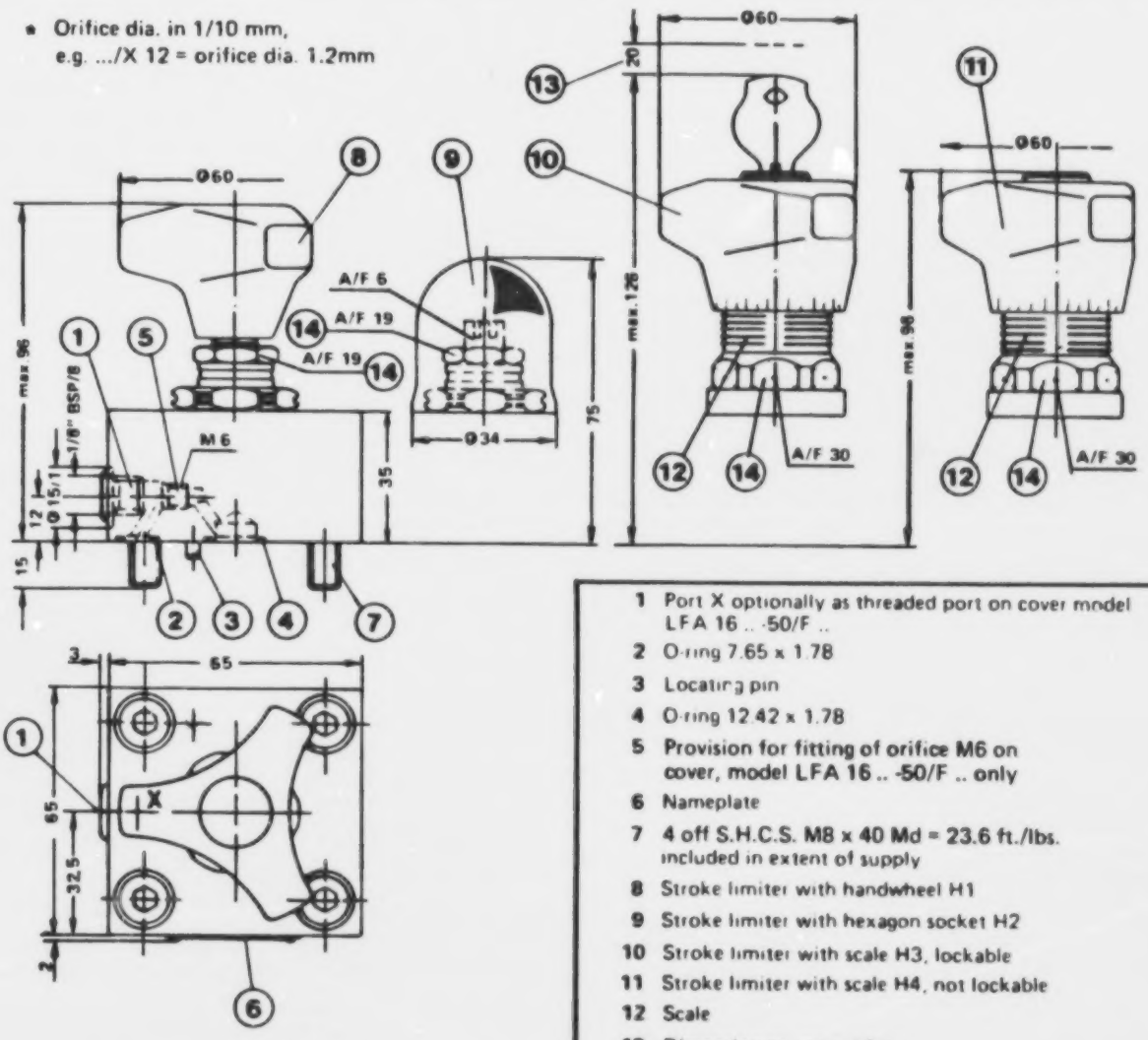
Without remote control port X (only without orifice) = no desig
With remote control port X = F

Further details to be stated in text

no desig = Petroleum based hydraulic fluids
V = phosphate ester

no desig = without orifice
X ... = • orifice effective in line X + orifice dia. (for model with remote control port X only)

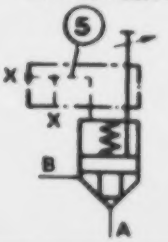
• Orifice dia. in 1/10 mm,
e.g. .../X 12 = orifice dia. 1.2mm



1 Port X optionally as threaded port on cover model LFA 16 .. -50/F ..
2 O-ring 7.65 x 1.78
3 Locating pin
4 O-ring 12.42 x 1.78
5 Provision for fitting of orifice M6 on cover, model LFA 16 .. -50/F .. only
6 Nameplate
7 4 off S.H.C.S. M8 x 40 Md = 23.6 ft./lbs. included in extent of supply
8 Stroke limiter with handwheel H1
9 Stroke limiter with hexagon socket H2
10 Stroke limiter with scale H3, lockable
11 Stroke limiter with scale H4, not lockable
12 Scale
13 Dimension to remove key
14 Locknut

LFA 16..-50/..

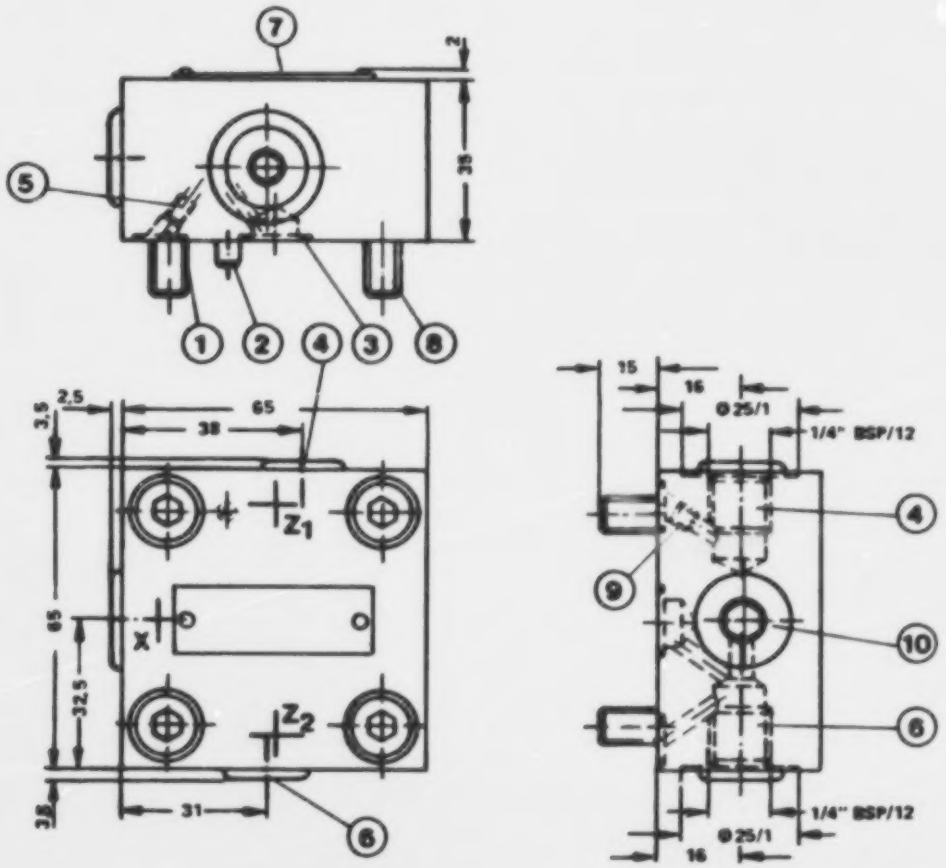
LFA 16..-50/F..



LFA 16 G 50	/	*

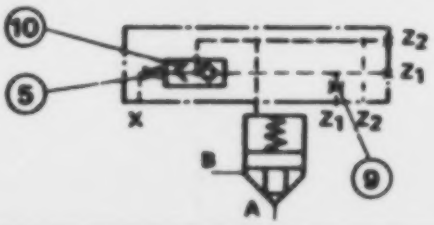
Petroleum based hydraulic fluids	= no desig.
Phosphate ester	= V

Further details to be stated in text



1 O-ring, 7.65 x 1.78 at ports X, Z1 and Z2
2 Locating pin
3 O-ring 12.42 x 1.78
4 Port Z1, optionally as threaded
5 Orifice dia. 1 (M6)
6 Port Z2, optionally as threaded port
7 Nameplate
8 4 off S.C.H.S. M8 x 40 Md = 23.6 ft./lbs. (included in extent of supply)
9 Orifice dia. 1 (M4)
10 Changeover valve size 6

LFA 16 G 50/..



APPENDIX II

SPECIFICATION SHEETS FOR AUXILIARIES

Electric Furnace

Induction Heater

Air Compressor

Oil Pump and Reservoir

Accumulator

SENTRY
HEAT TREATING

BULLETIN 1131

MODELS AY and AYP controlled atmosphere tool hardening furnaces

Model AY Furnaces Are Uniquely Different They Belong In Every Heat Treating Department

The AY Furnace design incorporates a full muffle with completely separate work and heating element chambers. This design offers the most economical arrangement for the Sentry Diamond Block which provides automatic atmosphere control for all high speed or air hardening steels.

In addition, the furnace features make them ideal for all types of heating applications . . . hardening, stress relieving, tempering and annealing are all within the abilities of these uniquely designed furnaces. Model AY and AYP Furnaces are worth the difference. Outstanding in routine production, yet suitable for short runs or intermittent service, these furnaces belong in every heat treating department.

Features of Model AY and AYP Furnaces

- Silicon carbide heating elements are located above and below the work chamber and are spaced to control heat distribution and insure temperature uniformity.
- Conservative electrical ratings allow for increase in resistance which occurs during heating element life.
- Work chamber formed by a high heat conducting, full silicon carbide muffle. Eliminates direct radiation from heating elements and unifies temperature of work area.
- Thermocouple located in heating chamber detects temperature change quickly . . . improves temperature control . . . extends operating range.
- The recessed door construction eliminates a "cold throat" condition and increases the usable work area.
- Size 1 through Size 4 furnaces with new heating elements will heat to 2200°F in 60 minutes or less. The Size 5 will require about 75 minutes.
- Insulated for continuous operation at 2500°F . . . ideal for heavy industrial production.
- Operating range of 300° to 2500°F. Plus low heat storage insulation and quick heating . . . ideal for intermittent use.
- Heavy steel furnace shells lined with best refractory materials for long life. Simplified maintenance a prime design feature.

Sentry AY Furnace Operating Characteristics & Specifications

Size & Model		1 AY	2 AY	3 AY	4 AY	5 AY
Work chamber Size*	Wide	4½	4½	8⅞	6⅛	8⅞
	High	2	4	4	6⅛	7
	Deep	9	11	16	13¾	20
Sentry Diamond Block Sizes		1-3	1-4	11-14	6-10	11-17
Sentry Block Max. Tool Size Capacity		⅞x2⅞x6	2¾x3x8	2½x7x12	4½x4¾x9	5x7x14
Max. Operating Temp.		All sizes to 2500°F				
Heating Time to 2200°F		60 min.	60 min.	60 min.	60 min.	75 min.
Power Supply		All sizes — 220 Volts, 60 Cycles, 3 Phase				
Rating (Kw.)		8.5	14.5	24	20	33
Avg. Power Used (Kw.)		2-4	3-7	5-12	4-10	6-14
Heating Elements		6	6	6	6	9
Element Connection		Wye	Wye	Wye	Wye	Delta
Avg. Element Life		All sizes — 1000 Heat Hours				
Dimensions (Excluding Door Lever Assembly)						
Pedestal Models	Width	24½	26	32	29¾	38¼
	Depth	24	28½	38¾	34¾	39½
	Height	52¾	57	65	66	65¾
Bench Models	Width	24½	31¼	—	29¾	—
	Depth	21	23¾	—	29¼	—
	Height	26	29¾	—	35½	—
Approx. Weight (Lbs.)						
Pedestal Model		310	470	850	775	1575
Bench Model		300	460	—	725	—

* All dimensions are in inches

Automatic Atmosphere Control
With Sentry Diamond Blocks

Model AY and AYP Furnaces are designed to provide a correct application of the Sentry Diamond Block Method of Atmosphere Control which produces the finest quality of High Speed Steel Hardening at a surprisingly low production cost. Some of the advantages of this method are listed below:

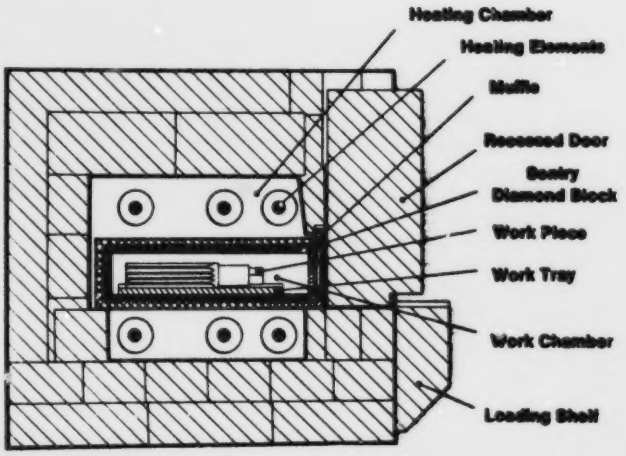
- Simplified Heat Treating System in which the atmosphere is automatically generated without operator supervision.
- Critical neutral point between carburization and decarburization automatically maintained. Full hardness without scale is the result.
- Hardening operation so simplified that unskilled operators can handle several furnaces.
- Tools have a pleasing gun metal finish with maximum hardness and toughness. Sharp corners are maintained.
- Toolmaking economies result as grinding and finishing operations are reduced or eliminated.
- Equipment costs considerably less than competitive methods employing gas generators or salt baths.
- Clean, safe, quiet procedure . . . no furnace deterioration.
- The most important benefit . . . better tools for longer production runs, less downtime, higher output . . . real production economies.

The high carbon monoxide atmosphere maintained in the Diamond Block chamber is truly neutral with regards to scale, carburization and decarburization of the steel. The method is ideal for all types of tungsten, molybdenum and cobalt high speed steel and also for high carbon high chrome, air hardening and other steels heat treated above 1700°F. Bulletin 1132 provides complete information on the Sentry Diamond Block Method.

Model AY . . . For Better Tool Heat Treating

The cutaway shows some of the unique construction details which set these furnaces apart. The dual chambers, the heating element arrangement, the full muffle, the recessed door, all contribute to make the Model AY a better furnace. Quick heating, uniformly heated work chamber, accurate temperature over a wide range and simple operation are characteristics which have made these furnaces accepted as the standard for tool heat treating. In addition, the Diamond Block inner chamber provides the only method of automatic atmosphere control which will produce consistent quality heat treating at low cost and without need of expensive equipment and skilled supervision.

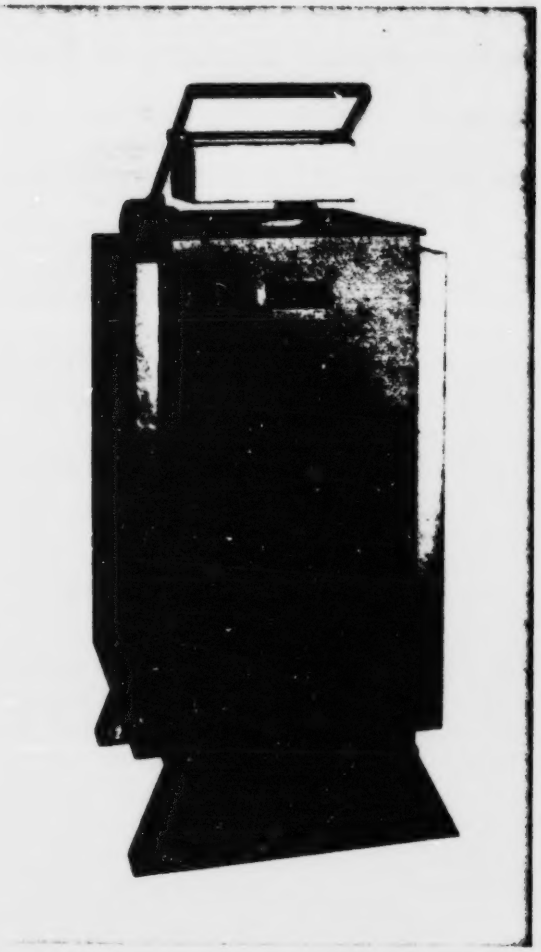
The cost of production relates directly to the quality of the production tools. Better tool heat treating offered by Model AY furnaces is a key to production economy.



Sentry Model AYP Vertical Electric Furnaces

These furnaces meet the requirements for hardening long or large tools which are best handled and heated in a vertical position. They are similar in general specifications to the model AY furnaces, incorporating all the advantages of full muffle construction and the use of Diamond Blocks to provide an automatic atmosphere control system.

The counterbalanced, lift-type door remains clear of the chamber opening when in the raised position, keeping the hot face at a safe distance from the operator. Loose insulating bricks supplied for the top opening can be arranged to close muffle opening and support tool holders by notching, drilling or slotting.



Sentry AYP Furnace — Operating Characteristics and Specifications

Size	Muffle Chamber Dimensions		Diamond Block Size	Diamond Block Tool Cap.	Heating Elements	Electrical Connection	Maximum Rating	Overall Dimensions Not Including Door			Approx. Wt. - Lbs.
	Opening	Depth					kw.	Wide	Deep	High	
2	4"x4½"	11"	4	2¾"x3"x8"	6	220 V. 3-Phase	14.5	29"	24"	29½"	600
2B	4"x4½"	28"	4B	2½"x2¾"x23"	12	220 V. 3-Phase	29.0	29"	24"	46"	850
4	6"x6"	13¾"	10	4½"x4½"x8"	6	220 V. 3-Phase	20.0	31"	28"	30"	800
4B	6"x6"	40"	10B	4¼"x4¼"x34"	12	220 V. 3-Phase	40.0	31"	28"	56"	1600

Sentry's full line of heat treating equipment also includes: Recirculating-Air Tempering Furnaces . . . Quenching Systems . . . Salt and Lead Pot Furnaces . . . Atmosphere Retorts . . . Laboratory Tube Furnaces . . . High and Low Temperature General Purpose Furnaces.

The Sentry Company, Foxboro, Massachusetts 02035

SENTRY HEAT TREATING

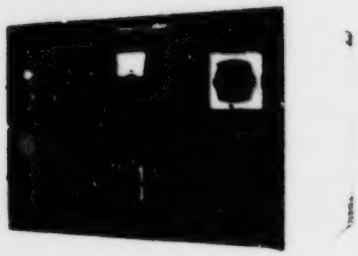
Complete Line of Furnaces and Accessories.

Printed in U.S.A.

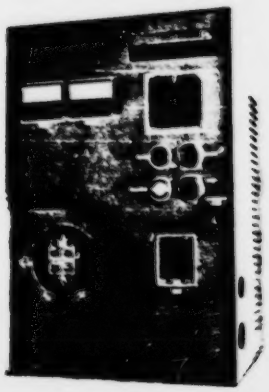
LINDBERG / CycleDyne

Induction heating systems

Making heat do more



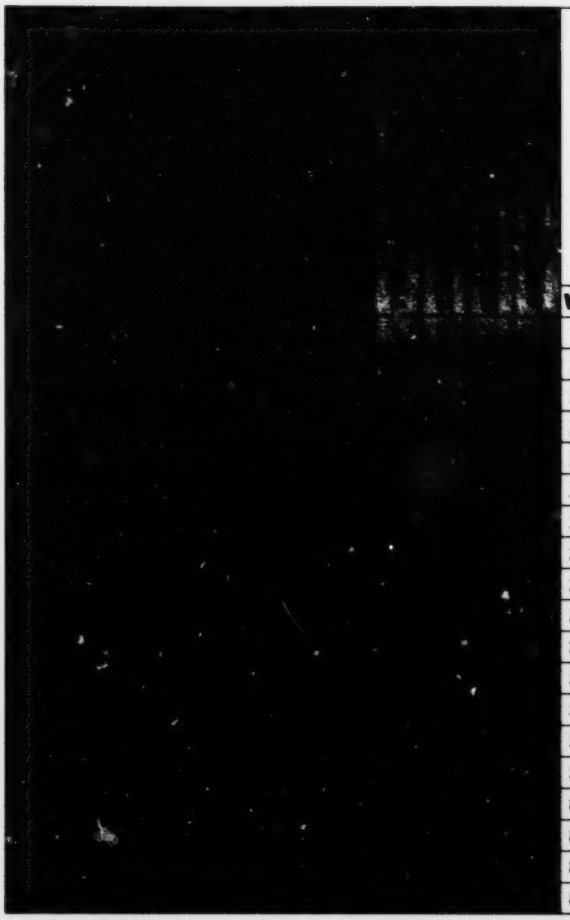
series "A" induction heaters
Space-age table-top model features more application oriented optional accessories than any other compatible design in today's market. Features rapid, localized, controlled heat for heat treating, brazing, soldering, cap sealing, annealing, melting, or just about any application requiring lower power levels. Series "A" provides exceptional loadability, excellent repeatability, and ease of operation.



series "AA"
high frequency induction heaters
Compact bench model is a favorite in laboratories, electronic and precious metalworking industries, and wherever space requirements are critical. Advanced control circuit provides single knob tuning, repeatable heat cycles, simplicity of work coils and loadability.

series "B" induction heaters
Floor mounted Series "B" induction heater is designed for minimum floor space. Swing-out panels provide easy access to all components. A compact unit designed for heat treating, brazing or soldering applications, as well as any other application requiring heating or special applications requiring high voltage tank circuits.

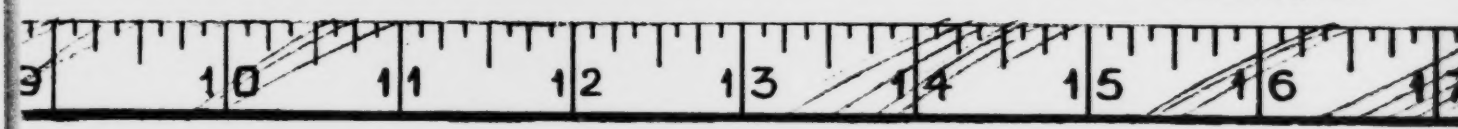
series "C" induction heaters
Innovative design features and reliability are the reasons for the Series "C" induction heaters' popularity. A favorite of the commercial heat treater because it can withstand heavy-duty operation as well as 24-hour continuous operation. This model features more accessories than any other induction heater on the market.



CABINET SIZE				FEATURES AVAILABLE						COOLING SYSTEMS			
W"	D"	H"	W LBS	SCR Control	Two Station	Single Station	R.T.L.	Remote OSC.	Remote Head	Water/Air	Water/Water	Refrigeration	Evaporative
16	15	24	153	•		•				•	•	•	
27	22	19	275	•	•	•	•		•	•	•	•	
27	22	19	375	•	•	•	•		•	•	•	•	
27	28	54	800	•	•	•	•		•	•	•	•	
27	28	54	950	•	•	•	•		•		•		
27	28	54	1100	•	•	•	•		•		•		
27	28	54	1200	•	•	•	•		•		•		
27	28	54	1300	•	•	•	•		•		•		
27	28	54	1500	•	•	•	•		•		•		
38	60	78	2400	•	•	•	•	•	•		•		
38	60	78	2700	•	•	•	•	•	•		•		•
38	60	78	2900	•	•	•	•	•	•		•		•
38	60	78	3300	•	•	•	•	•	•		•		•
38	60	78	3500	•	•	•	•	•	•		•		•
38	60	78	3900	•	•	•	•	•	•		•		•
80	80	80	6500	•	•	•	•		•		•		•
80	80	80	6700	•	•	•	•		•		•		•
80	80	80	7100	•	•	•	•		•		•		•
80	80	80	7400	•	•	•	•		•		•		•

• — Indicates Available

All specifications subject to change without notice.
All dimensions are approximate



Ink drying
Lindberg/Cycle-Dyne is providing systems that deliver continuous controlled heat for static and in-line processes. Ink is dried on steel tape at a rate of 200 ft./minute. Infrared control system maintains proper processing temperature.

standard equipment

solid state rectifier

Controls
- Start-stop heat cycle pushbuttons
- Filament and plate pilot light indication
- Heat cycle timer ("A" and "B" models)
- Load meter
- Grid meter
- Plate voltage meter ("C" and "D" models)
- Line voltage matching transformer taps

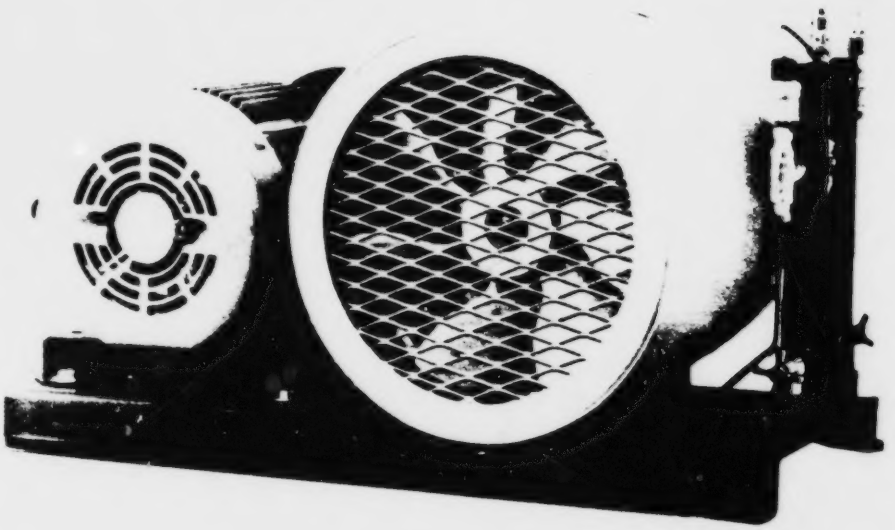
Protective Devices
- Main line circuit breaker
- Load overload relay
- Filament time delay relay
- Water circuit temperature and flow switches
- Door and panel interlock switches
- Transformer surge protection

FCC Certification
Water to air cabinet cooling
("C" and "D" models)
Internal or external heat station
Loading via direct tank or output transformer

optional equipment

- SCR output control, 0.5% or 2% regulation
- Single or multiple remote heat station
- Electronic grid keying
- Pulse keying and cycling
- Optical heat sensing with automatic power control
- Remote oscillator, single or multiple operations up to 500 ft. from power supply
- Dual frequency output on two position stations
- Tapped inductance output
- Quick coil disconnects
- Saturable reactor control
- Refrigeration or evaporative cooling systems to suit application
- Special enclosures to meet JIC, FDA or automotive specifications
- Special output power parameters to meet food packaging requirements

SA "SWEET AIR" SERIES
OIL-FREE HIGH PRESSURE
BREATHING AIR FILL STATION



RIX

SA-6E / OPTION PACKAGE #2
STANDARD EQUIPMENT LIST AND
PROCUREMENT SPECIFICATIONS

These Oil-Free High Pressure Breathing Air Compressors are Expressly Designed for Filling Air Cylinders (SCBA) for Fire & Rescue Service, SCUBA Diving, and Industrial Pure Air Use.

RIX INDUSTRIES • 6460 Hollis Street, Oakland, CA 94608 USA • (415) 658-5275 • Telex 33-7724

SA *SWEET AIR* SERIES OIL-FREE HIGH PRESSURE BREATHING AIR FILL STATION

APPLICATIONS:

Filling self-contained breathing apparatus backpacks used by: SCUBA divers, firefighters, rescue squads, industrial "hazardous environment" workers.

YOUR AIR IS YOUR LIFE

Breathing air used in SCBA cylinders must be free from contaminants. Because all oil-lubricated compressors contaminate the air during the compression process, RIX Industries, professionals in manufacturing **oil-free** breathing air compressors, dedicated their research/development activities to producing this line of compressors. There are two major advantages to the RIX *Sweet Air* **Oil-free** compressors over oil-lubricated compressors: **Safety** and **Reliability.**

SAFETY — The RIX *Sweet Air* SA-3 and SA-6 breathing air compressors are **totally oil-free. Oil-free** means that there is no lubricating oil inside the compressor. It is impossible for these compressors to create oil mist or carbon monoxide. Thus, it is impossible for these contaminants to be caused by the compressor and compressed into the breathing air. The result is safer compressed breathing air. Regardless of the age or condition of the compressor, they can never contribute to a reduction in air quality, or the possible poisoning of the breathing air. **Oil-free** means no oil mist or carbon monoxide caused by the compressor — ever!

RELIABILITY — Service on the RIX *Sweet Air* **oil-free** compressor is simple and easy. It requires no special tools or technical abilities. Since there is no "oil-bath" crankcase, as in lubricated compressors, the parts requiring normal service and maintenance are easily accessible. Compression pistons and rings can be removed and replaced without disturbing high pressure lines, cylinder heads, valves, etc. Rebuilding can occur in the field with a minimum of parts and tools, requiring very little time.

SA-6E/OPTION PACKAGE #2

This High Pressure Breathing Air Fill Station (illustrated on opposite page) is designed to charge 2215 psi SCBA cylinders and 3000 psi SCUBA cylinders. By adding (A4472) 5000 psi maximum pressure option to the compressor, 4500 psi SCBA cylinders may also be charged. The system has sufficient capacity to efficiently service up to approximately 60 self-contained breathing apparatus being used under normal fire department operation. The Air Storage (cascade) system can be either 2400, 3600 or 5000 psi. The easy to use wall mounted controls allow for convenient installation and flexibility of arrangement between the wall mounted option package and compressor.

NOTE: When ordering this system, be sure to determine whether or not the 5000 psi maximum pressure option is necessary for your operation. Also, determine the electric power requirements (208, 230 or 460 volt, single or three phase). Three phase motor is standard, single phase motor (107-418) is optional.

SPECIFICATIONS — SA-6E oil-free compressor

Drive	Model	Max PSI	SCFM	Dimensions	Weight	Comments
elec.	SA-6E	3300*	5.5	30"Lx18"Wx18"H	182 lbs	5 hp, 230 volt, 3 phase, standard Optional 5 hp, 1 phase available

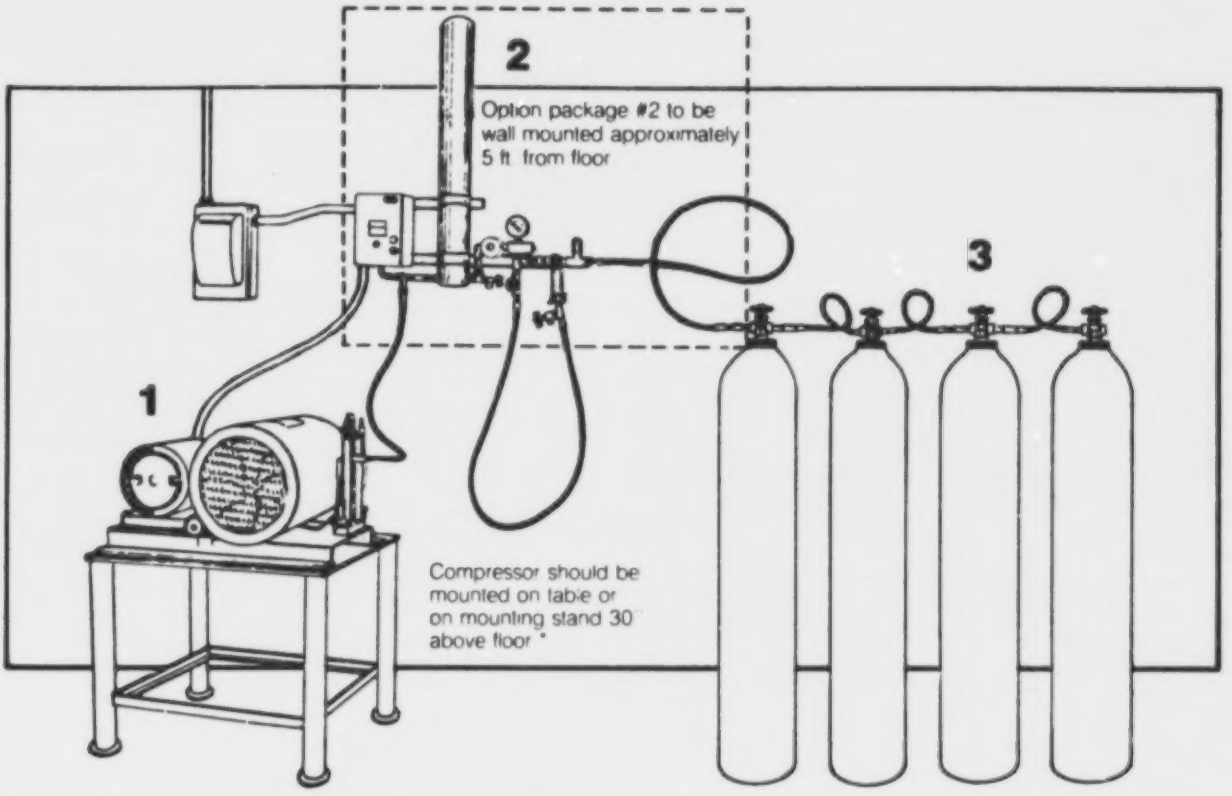
*5000 PSI option available

Consistent with RIX Industries' policy to continually improve its products, RIX reserves the right to change specifications, dimensions, and prices without prior notice.

DISTRIBUTED BY

High Pressure Breathing Air Fill Station

SA-6E/OPTION PACKAGE # 2


2
Option package #2 to be wall mounted approximately 5 ft. from floor
3
1
Compressor should be mounted on table or on mounting stand 30" above floor *

1

SA-6E OIL-FREE COMPRESSOR

Standard items include:

- 3 stage, 5.5 cfm, 3300 psi compressor
- 5 h.p., 208/230/460 volt, 3 phase motor
- Motor starter
- Dual moisture separators
- Intercoolers and aftercooler
- Air cooling fan and shroud
- Pulley, belt drive and belt guard
- Formed steel bedplate
- Air intake hose with filter/silencer
- Rix grease and grease gun
- Operating and maintenance manual

AVAILABLE OPTIONS

- (A4472) 5000 psi max pressure
- (107-418) single phase motor

2

AIR PURIFICATION OPTION PACKAGE #2

Option package #2 includes:

- Hour meter
- Inlet check valve
- Adjustable pressure switch
- 3 lb. air purification system
- Visual indicator
- Bleed valve
- Back-pressure regulator
- Pressure gauge
- Air discharge control valve
- 5 ft. high pressure filling hose
- Bleed valve
- SCBA adapter, or SCUBA yoke (optional)
- Fill assembly holder
- Air storage (cascade) control valve
- Safety relief valve (2400, 3600 or 5000 psi)
- 5 ft. air storage (cascade) hook-up hose
- CGA 346 nut & nipple (air storage hook-up)
- Wall mounting brackets
- Complete package pre-assembled

3

HIGH PRESSURE AIR STORAGE SYSTEM

System includes:

- 3600 psi D.O.T., 400 cu. ft. per tank; or 5000 psi A.S.M.E., 430 cu. ft. per tank
- 1 to 6 or more cylinders available
- Tank valves
- Tee fittings
- Pig tails

*Mounting stand to be provided by customer.

PROCUREMENT SPECIFICATION

PURCHASING INFORMATION

RESPIRATORY AIR SYSTEM IN ACCORDANCE WITH OSHA REQUIREMENTS

PURPOSE:

The system shall be used to charge self-contained breathing apparatus with purified high pressure breathing air suitable for human respiration.

GENERAL:

Air purity shall meet or exceed the standards of the Compressed Gas Association Specification G-7.1 for Grade D, E, or F Breathing Air.

Pressure vessels shall have four-to-one safety factor and shall be designed and fabricated in accordance with the ASME code for Unfired Pressure Vessels.

All tubing shall meet NFPA, SAE, JIC and ANSI standards.

All valves shall meet the applicable National Codes such as those of the Bureau of Explosives, DOT and CGA.

The entire air system shall meet all requirements established by the Occupational Safety and Health Act, otherwise known as OSHA.

All equipment supplied shall be new. Used or surplus equipment is unacceptable.

Identification:

All major components and accessories are to be clearly identified with permanently affixed nameplates stating the make, model, and serial number. Other pertinent information such as capacities, pressures, voltages, currents, etc., are to be indicated in the proper manner.

Instructions:

Appropriate tags and warning labels shall be affixed where necessary for safety and ease in the operation and adjustment of the valves, switches and controls.

One bound manual containing information on operation, maintenance, troubleshooting, and replacement parts shall be delivered with the system.

Packing and Shipping:

The air system will be properly packaged to protect against damage during shipment.

AIR COMPRESSOR ASSEMBLY:

The system shall incorporate a three stage, axial-piston design, air compressor with relief valves and cooling after each stage of compression. The compressor shall be an oil-free (oil-less) compressor that operates totally without lubricating oil. The compressor shall be air cooled, including cooling fan and shroud, two moisture separators, steel bedplate, inlet filter, and belt guard.

The compressor shall have the following continuous duty rating:

Charging rate shall be 5.5 SCFM at _____ (3300 psi or 5000 psi). Power shall be provided by a 5 hp _____ (single or 3 phase), _____ (208, 230 or 460 volt), 60 cycle, 3450 RPM motor. Appropriate magnetic starter to be included with electric motor.

The compressor assembly shall be built in a workmanlike manner utilizing sound engineering practices. The assembly shall be designed to allow for maximum compressor cooling and for ease of maintenance.

PURIFICATION SYSTEM/ COMPRESSOR CONTROL PACKAGE:

Air purity shall meet or exceed the standards of the Compressed Gas Association Specification G.7.1, Grade D, E or F Breathing Air.

The filter chambers shall be constructed of aluminum alloy and designed for a 4-1 safety factor at 5000 PSIG working pressure. They shall meet the ASME standards for "Unfired Pressure Vessel Code, Section VIII."

The Purification System shall be designed to purify the air by chemical absorption of water vapor and conversion of carbon monoxide to carbon dioxide through catalytic action. The system must also be capable of removing solid particles of 5 microns in size.

The Purification System shall be designed to utilize disposable chemical cartridges. Each cartridge shall incorporate a 5 micron filter to prevent chemical dust from passing through the system.

The Purification System/Compressor Control Package shall consist of the following:

- Hour meter
- Inlet check valve
- Adjustable pressure switch
- 3 lb. air purification system
- Visual indicator
- Bleed valve
- Back-pressure regulator
- Pressure gauge
- Air discharge control valve
- 5-ft. high pressure filling hose
- Bleed valve
- SCBA adaptor, or SCUBA yoke (optional)
- Fill assembly holder
- Air storage (cascade) control valve
- Safety relief valve _____ (2400, 3600 or 5000 psi)*
- 5 ft. air storage (cascade) hook-up hose
- CGA 346 nut & nipple (air storage hook-up)
- Wall mounting brackets
- Complete package pre-assembled

*Relief valve setting should correspond to the pressure rating of the air storage (cascade) system being used.

OPTIONAL ITEMS:

The following optional items shall be included:

_____

_____

AIR STORAGE SYSTEM: DOT/ASME

Air storage system to include _____ DOT tanks, of _____ psi rating, _____ cubic feet per tank, complete with all fittings, plumbing, and hardware necessary to operate as a cascade system. System to include Tank Valves (with safety burst discs), Tee fittings, and pigtail connectors.

ASME air storage system to include _____ ASME tanks of 5000 psi rating, 430 cubic feet per tank, complete with all fittings, plumbing, and hardware necessary to operate as a cascade system. System to include tank valves, tank rack, relief valves, tee fittings and pigtail connectors.

Rectangular Reservoirs
Size 10 to 500 Gallons

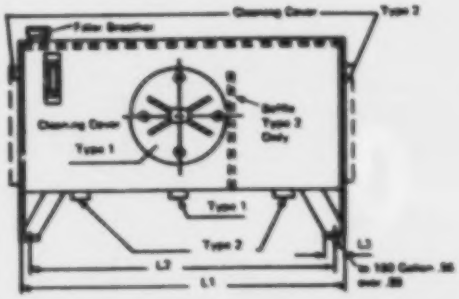
Features
- Tank with Feet
- Cleaning Cover
- Drain Plugs
- Oil Level Indicator
- Filler Breather
- Built-on Drip Pan (Res. top reset)

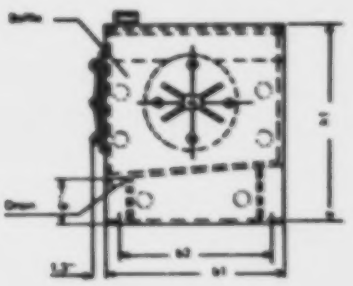
Available in 2 Types

Type 1 = PU-A 40 - 01.01
One cleaning cover - without baffle

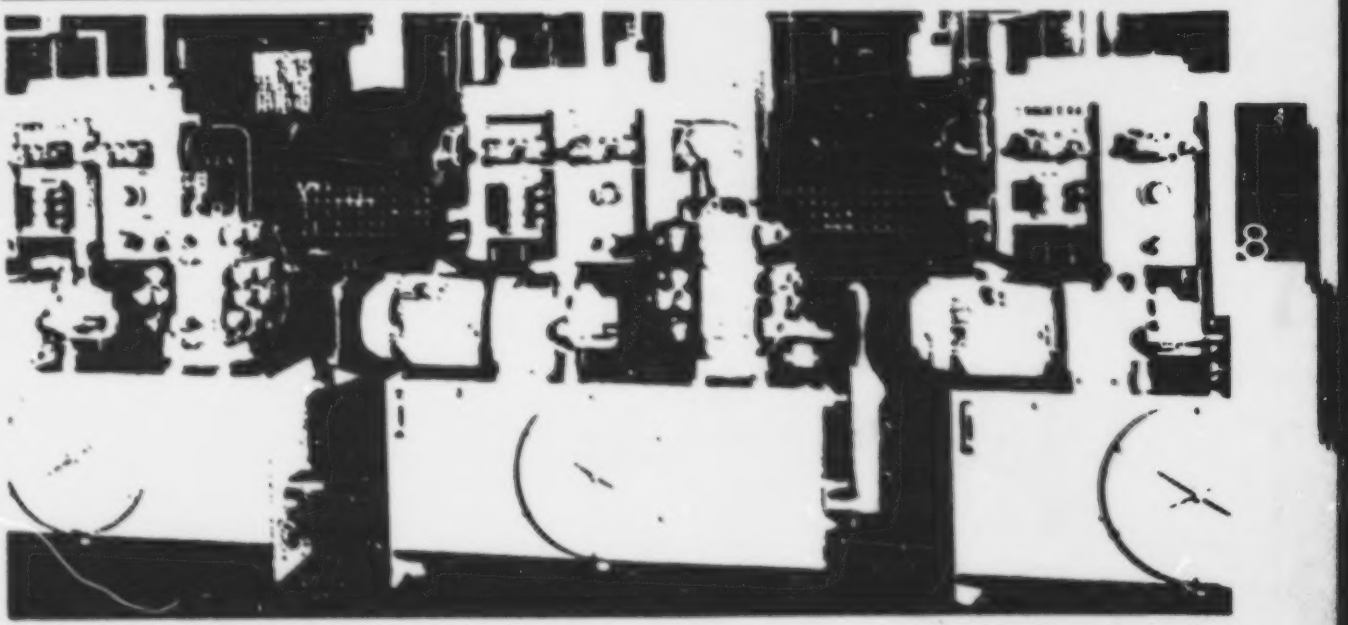
Type 2 = PU-A 40 - 01.02
Two cleaning covers - with baffle

80 Type 1 840 004
- SIZE (Gallon)
- STYLE = 1 or 2
- ASSEMBLY NO. - Order No. (See below)



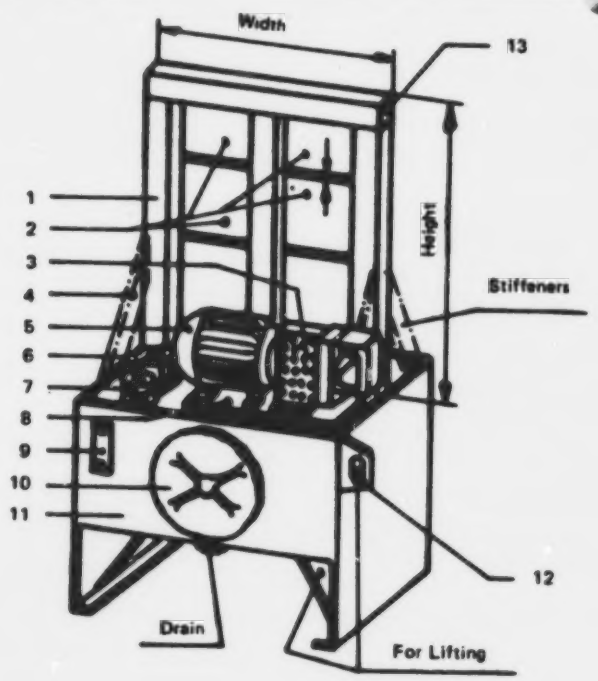


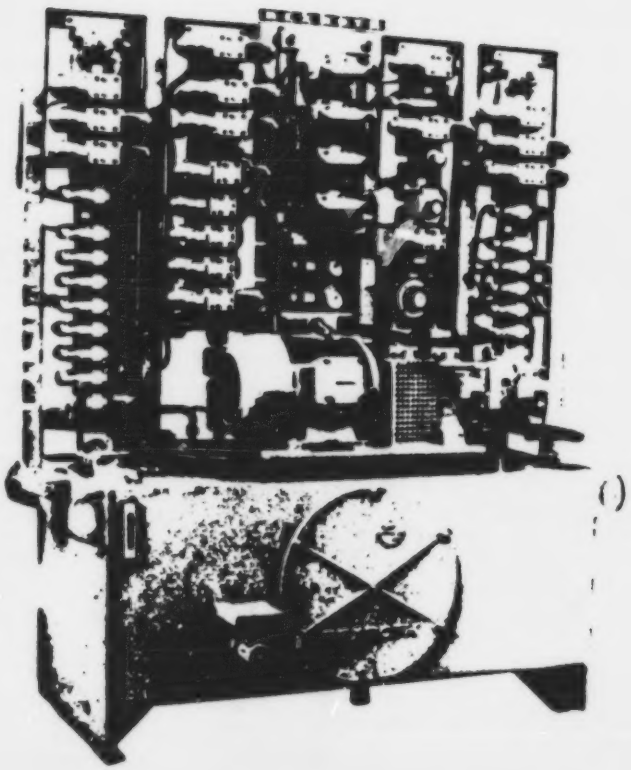
Gallon	Liter	Order No. Type 1	Order No. Type 2	h1	h2	L1	L2	L3	h3
10	38	840 029		13.00	11.00	30.00	17.50	2.00	18.00
20	76	840 001	840 013	15.00	15.00	34.33	21.75	2.00	21.00
30	114	840 002	840 014	20.75	18.75	36.33	27.00	2.50	31.44
40	151	840 003	840 015	20.75	18.75	36.38	33.00	2.50	27.75
60	227	840 004	840 016	24.00	21.00	42.38	39.00	2.50	34.25
80	303	840 005	840 017	30.00	27.00	42.38	39.00	2.50	35.38
100	378	840 006	840 018	30.00	27.00	42.38	39.00	2.50	36.38
120	454	840 007	840 019	30.00	27.00	48.00	45.00	2.75	30.25
150	568	840 008	840 020	30.00	27.00	60.00	57.00	2.75	30.25
200	757	840 009	840 021	36.00	33.00	72.00	69.00	2.75	30.81
300	1136	840 010	840 022	36.00	33.00	72.00	69.00	3.00	36.00
400	1514	840 011	840 023	36.00	33.00	84.76	80.76	3.00	42.19
500	1892	840 012	840 024	42.00	39.00	84.76	80.76	3.00	44.76



PowerUnits Segmented Design

1. Segment Frame
2. Segment Panel
3. Coupling Guard
4. Stiffener
5. Electric Motor
6. Return Line Filter
7. Filler Breather
8. Base Frame
9. Sight Glass
10. Clean Out Cover
11. Reservoir
12. Lifting Lug
13. Plastic Plug





Design for Valves:
D01 - Size 6
D02 - Size 10
D04 - Size 16

Ideal Design For:

- Modular systems
- Low noise power units
- Standardized design with stocked parts
- Short deliveries

HYDRAULIC ACCUMULATOR SPECIFICATIONS

TYPE	:	Piston
SERVICE	:	Air/oil at 4500 psi.
SIZE	:	25 U.S. gallons. 16 inches O.D. x 70 inches high. 2200 pounds.
DISCHARGE	:	3 inch SAE flange.
MANUFACTURE:		Code approved and certified.

APPENDIX III

INSTRUMENTATION SPECIFICATIONS

PRODUCT DATA SHEET 2258
(Replaces PDS 2197)

MODEL 1151HP ALPHALINE DIFFERENTIAL PRESSURE TRANSMITTER FOR HIGH LINE PRESSURES

4500 psi operating pressure

6750 psi test pressure

Ranges from 25" H_2O to 300 psid

Compatible with any 2-wire system

0.25% accuracy

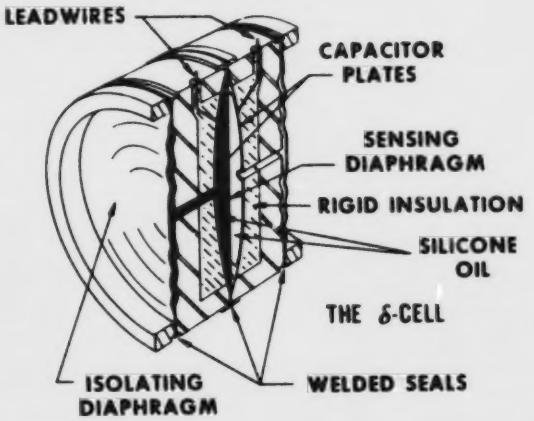
On 4–20 mA output:

- *Up to 600% elevation or 500% suppression*
- *Adjustable damping*

FEATURES

The ALPHALINE® Differential Pressure Transmitter* now provides accurate differential measurement for line pressures up to 4500 psi. Confident application in high line pressure systems is assured with static pressure protection to 6750 psi and full overpressure protection to 4500 psi without damage to the transmitter. Direct electronic sensing with the completely sealed δ-CELL™ capacitance sensing element eliminates mechanical force transfer and the associated problems with vibration and shock.

Installation and commissioning are simplified by compact design, 2-wire system compatibility, external span and zero adjustments and explosion-proof, weather-proof construction. Wiring terminals and electronics are in separate compartments, so the electronics remain sealed during installation. Reverse polarity protection keeps wiring mishaps from costing money. Maintenance costs are reduced by the use of solid state plug-in printed circuit boards which are interchangeable among all Rosemount 1151 transmitters.



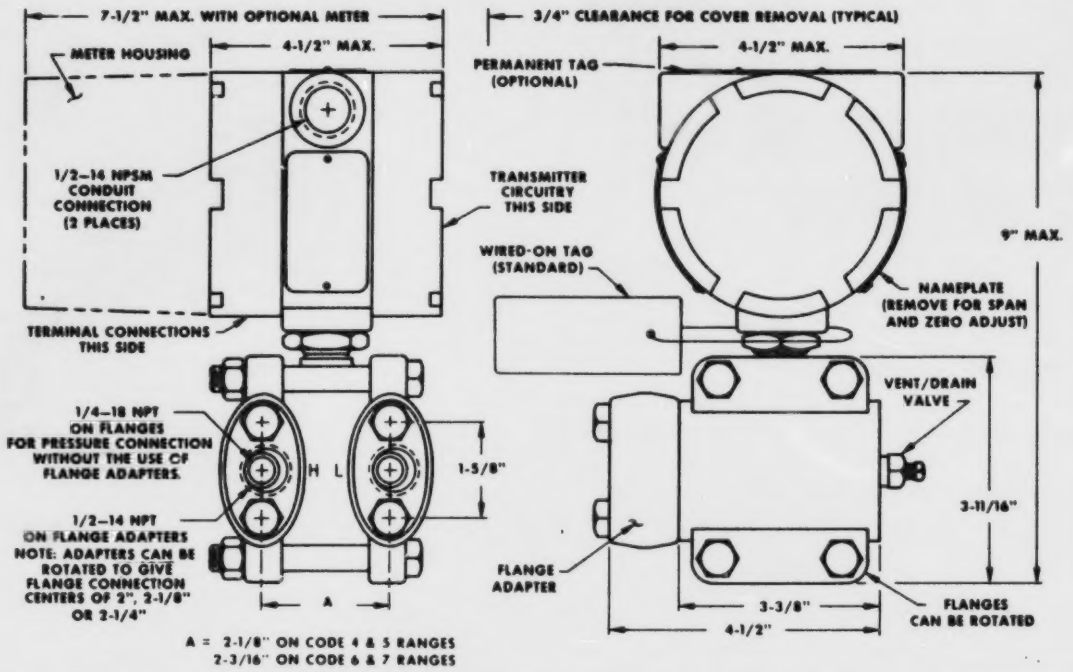
OPERATION

Process pressure is transmitted through isolating diaphragms and silicone oil fill fluid to a sensing diaphragm in the center of the δ-CELL. The sensing diaphragm functions as a spring element which deflects in response to differen.. pressure across it. The displacement of the sensing diaphragm, a maximum motion of 0.004 inches, is proportional to the differential pressure. The position of the sensing diaphragm is detected by capacitor plates on both sides of the sensing diaphragm. The differential capacitance between the sensing diaphragm and the capacitor plates is converted electronically to a 2-wire, 4–20 mADC or 10–50 mADC signal.

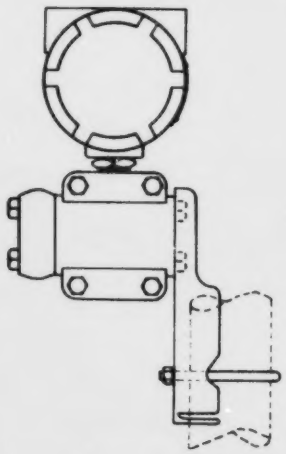
Rosemount

Copyright Rosemount Inc., 1971, 1975, 1976
*Protected by one or more of the following U.S. Patents: No. 3,271,669; 3,318,153; 3,618,390; 3,646,538; 3,793,885; 3,800,413; 3,854,039; 3,859,594 and 3,195,028. Canada Patented 1968, 1974 and 1975. Patente Mexicana No. 118892. Other U.S. and Foreign Patents issued or pending.

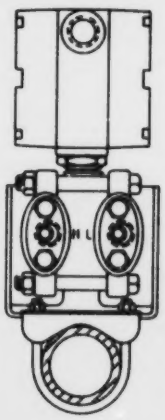
Dimensional Drawings

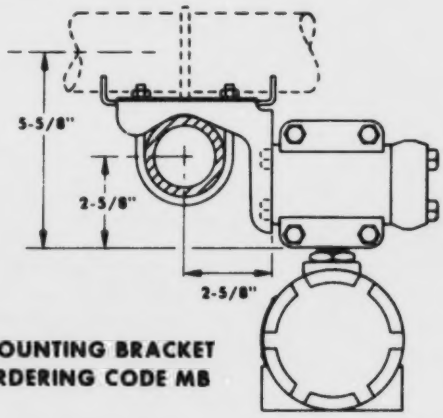

7-1/2" MAX. WITH OPTIONAL METER
4-1/2" MAX.
METER HOUSING
1/2–14 NPSM CONDUIT CONNECTION (2 PLACES)
TERMINAL CONNECTIONS THIS SIDE
1/4–18 NPT ON FLANGES FOR PRESSURE CONNECTION WITHOUT THE USE OF FLANGE ADAPTERS.
1/2–14 NPT ON FLANGE ADAPTERS NOTE: ADAPTERS CAN BE ROTATED TO GIVE FLANGE CONNECTION CENTERS OF 2", 2-1/8" OR 2-1/4"
H L
1-5/8"
A
A = 2-1/8" ON CODE 4 & 5 RANGES
2-3/16" ON CODE 6 & 7 RANGES
3/4" CLEARANCE FOR COVER REMOVAL (TYPICAL)
4-1/2" MAX.
PERMANENT TAG (OPTIONAL)
TRANSMITTER CIRCUITRY THIS SIDE
WIRED-ON TAG (STANDARD)
9" MAX.
NAMEPLATE (REMOVE FOR SPAN AND ZERO ADJUST)
VENT/DRAIN VALVE
3-11/16"
FLANGE ADAPTER
3-3/8"
4-1/2"
FLANGES CAN BE ROTATED

OPTIONAL MOUNTING BRACKETS FOR 2" PIPE SHOWN IN TYPICAL MOUNTING CONFIGURATIONS

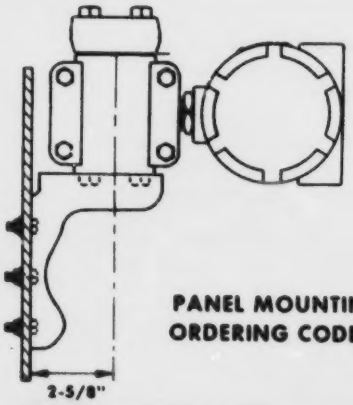


FLAT MOUNTING BRACKET
ORDERING CODE FB





MOUNTING BRACKET
ORDERING CODE MB



PANEL MOUNTING BRACKET
ORDERING CODE PB

Functional Specifications

Service

Liquid, gas or vapor.

Ranges

0–25/150" H_2O
0–125/750" H_2O
0–17/100 psid
0–50/300 psid

Outputs

4–20 mADC or 10–50 mADC.

Power Supply

External power supply required.
4–20 mADC: Up to 45 VDC.
Transmitter operates on 12 VDC with no load.
10–50 mADC: Up to 85 VDC.
Transmitter operates on 30 VDC with no load.

Load Limitations

See Figure 1.

Indication

Optional meter with 1¾" scale. Indication accuracy is ±2%.

Hazardous Locations

Explosion proof: Approved by Factory Mutual for Class I, Division 1, Groups B*, C and D; Class II, Division 1, Groups E, F and G; and Class III, Division 1. Certification by Canadian Standards Association (CSA) for Class I, Groups C and D available as an option. **Intrinsically Safe:** FM certification optional for Class I, Division 1, Groups B, C and D when used with listed barrier systems.

Span and Zero

Continuously adjustable externally.

Zero Elevation and Suppression

Regardless of output specified, zero elevation and suppression must be such that neither the span nor the upper or lower range value, exceed 100% of the upper range limit.
4–20 mADC Maximum zero elevation: 600% of calibrated span. Maximum zero suppression: 500% of calibrated span.
10–50 mADC Range 4 or 5 maximum elevation or suppression: 150% of span. Range 6 or 7 maximum elevation or suppression: 50% of span.

*Optional meter not approved for Group B.

Temperature Limits

–20° F to +200° F Amplifier operating.
–40° F to +220° F Sensing element operating.
–60° F to +250° F Storage.

Static Pressure and Overpressure Limits

Maximum rated static line pressure (operating): 4500 psig.
Maximum static line pressure (without damage): 150% of rated (6750 psig). 4500 psig pressure on either side without damage to the transmitter. 10,000 psig proof pressure on flanges.

Humidity Limits

0–100% RH.

Volumetric Displacement

Less than 0.01 cubic inches.

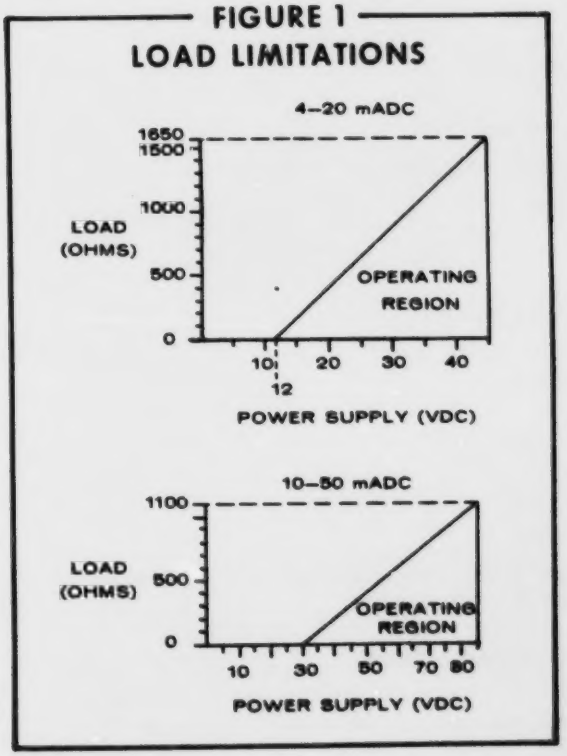
Damping

4–20 mADC: Time constant continuously adjustable between 0.2 and 1.67 seconds.
10–50 mADC: Time constant fixed at 0.2 second for ranges 4 and 5, and 0.1 second for ranges 6 and 7.

Turn-on Time

2 seconds. No warmup required.

FIGURE 1
LOAD LIMITATIONS



Performance Specifications

(ZERO BASED SPANS, REFERENCE CONDITIONS)

Accuracy

±0.25% of calibrated span. Includes combined effects of linearity, hysteresis and repeatability.

Dead Band

None

Stability

±0.25% of upper range limit for six months.

Temperature Effect

At Maximum Span (e.g. 0–100 psid for 0–17/100 psid range)

Zero Error: ±0.5% of span per 100° F. Total effect including span and zero errors: ±1.0% of span per 100° F.

At Minimum Span (e.g. 0–17 psid for 0–17/100 psid range)

Zero Error: ±3.0% of span per 100° F. Total effect including span and zero errors: ±3.5% of span per 100° F.

Overpressure Effect

Overpressure of 4500 psi will cause a zero shift of
less than ±1.0% of upper range (Range 4)
less than ±2.0% of upper range (Range 5)
less than ±5.0% of upper range (Range 6, 7)

Static Pressure Effect

Zero Error: ±2.0% of upper range limit for 4500 psi.

Span Error: $-1.0 \pm 0.25\%$ of reading per 1000 psi. This is a systematic error which can be calibrated out for a particular pressure before installation.

Vibration Effect

±0.05% of upper range limit per g to 200 Hz in any axis.

Power Supply Effect

Less than 0.005% of output span per volt.

Load Effect

No load effect other than the change in power supplied to the transmitter.

Mounting Position Effect

Zero shift of up to 1" H_2O which can be calibrated out. No span effect. No effect in plane of diaphragm.

Physical Specifications

Materials of Construction†

Isolating Diaphragms and Drain/Vent Valves:
316SS.

Process Flanges and Adapters:
Cadmium Plated Carbon Steel or 316SS.

Wetted O-Rings:
VITON.

Fill Fluid:
Silicone Oil.

Bolts:
Cadmium Plated Carbon Steel.

Electronics Housing:
Low-copper aluminum (NEMA4)

Paint:
Acrylic baked enamel.

Process Connections

1/4 NPT on flanges. 1/2 NPT with adapters.

Electrical Connections

1/2-inch conduit with screw terminals and integral test jacks compatible with miniature banana plugs (Pomona 2944, 3690 or equal),

Weight

12 pounds excluding options.

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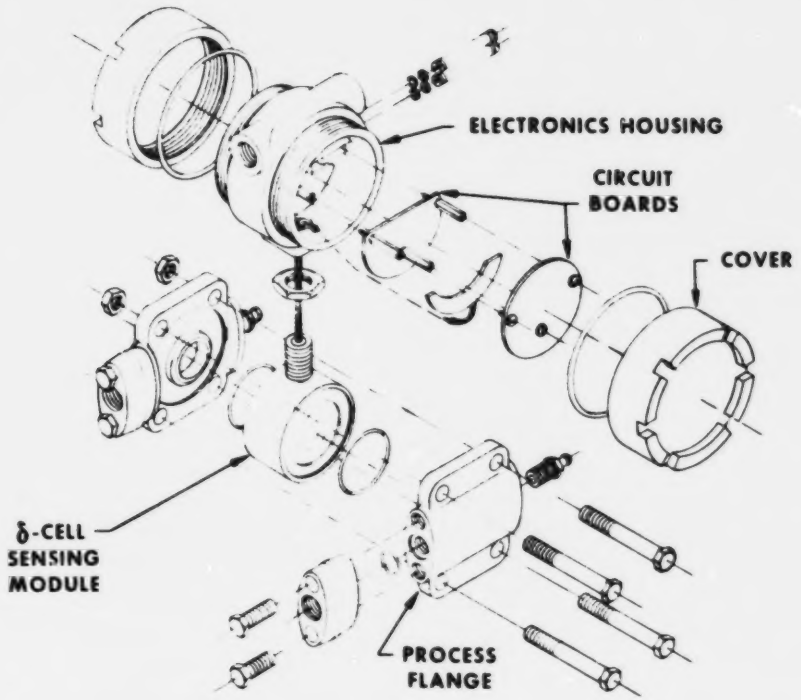
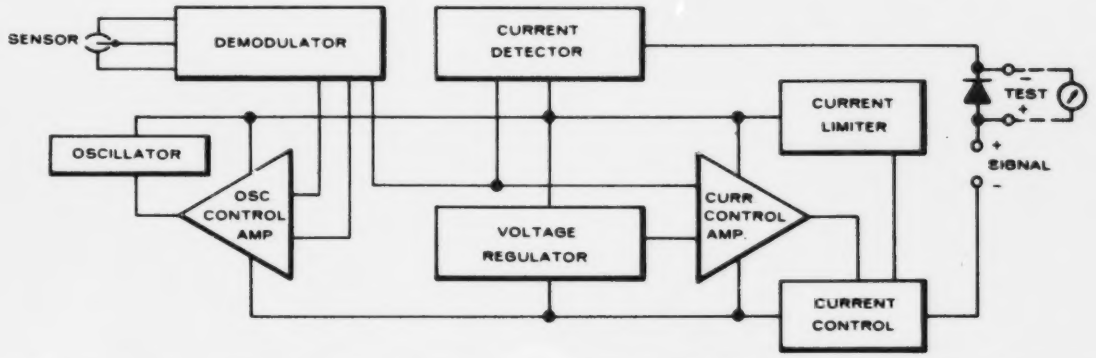
† VITON is a DuPont trademark.
Terminology per SAMA Standard PMC20.1-1973

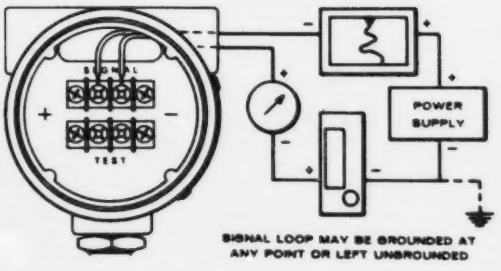
TYPICAL MODEL 1151 PRESSURE TRANSMITTER ASSEMBLY



Electrical Block Diagram



Wiring Connections



STANDARD ACCESSORIES All Models are shipped with flange adapter, vent/drain valve and one instruction manual per shipment.

TAGGING ALPHALINE Differential Pressure Transmitters will be tagged in accordance with customer requirements. All tags are stainless steel.

CALIBRATION Transmitters are factory calibrated to customer's specified span. If calibration is not specified, transmitters are calibrated at maximum range. Calibration is at ambient temperature and pressure.

Ordering Information

MODEL 1151HP	ALPHALINE DIFFERENTIAL PRESSURE TRANSMITTER

CODE	RANGES
4	0–25 to 0–150 inches H_2O (0–635 to 0–3810 mm H_2O)
5	0–125 to 0–750 inches H_2O (0–3175 to 0–19,050 mm H_2O)
6	0–17 to 0–100 psid (0–1.2 to 0–7.0 kg/cm^2)
7	0–50 to 0–300 psid (0–3.5 to 0–21 kg/cm^2)

CODE	OUTPUT
E	4–20 mADC w/adjustable damping
B	10–50 mADC w/fixed damping

CODE	MATERIALS OF CONSTRUCTION		
	FLANGES AND ADAPTERS	DRAIN/VENT VALVES	ISOLATING DIAPHRAGMS
12	Cadmium Plated C.S.	316SS	316SS
22	316SS	316SS	316SS

CODE	OPTIONS
LM	Linear Meter, 0-100% scale
SM	Square Root Meter, 0-10 scale
MB	Optional Mounting Bracket for Mounting to 2" Pipe
PB	Optional Mounting Bracket for Panel Mounting
FB	Optional Flat Mounting Bracket for Mounting to 2" Pipe
CE	Canadian Standards Association (CSA) Explosion Proof Certification for Class I, Groups C and D; Class II, Groups E, F and G; Class III; (Encl. IV).

INTRINSIC SAFETY APPROVAL (All Are Approved By Factory Mutual)

	OUTPUT CODES INCLUDED	BARRIER MANUFACTURER	BARRIER MODEL	CLASS I, DIVISION 1, GROUPS B	C	D
F1	E	Foxboro	2AI-12V-FGB	X	X	X
			2AI-13V-FGB	X	X	X
F2	E	Taylor	124S1134	X	X	X
			124S1144	X	X	X
			124S931		X	X
			124S932		X	X
			124S1254		X	X
			124S1264		X	X
F3	E	Westinghouse	75SB01	X	X	X
			56FC12		X	X
F4	E	Leeds & Northrup	316569*	X	X	X
			316747*	X	X	X
F5	E	Fischer & Porter	805H023U01		X	X
			805H027U01		X	X
			805H027U02	X	X	X
F6	E	Fisher	AC302*		X	X
F7	E	Honeywell	*			

*Pending

1151HP	4	E	22	LM,MB	← COMPLETED DESIGN SPECIFICATION

OPTIONAL THREE-VALVE MANIFOLDS

Part No. 1151-150-1*: 3-Valve Manifold, Carbon Steel (Anderson, Greenwood and Co., M4AVC)

Part No. 1151-150-2*: 3-Valve Manifold, 316SS (Anderson, Greenwood and Co., M4AVS)

*Available only for range codes 4 and 5.

Rosemount Inc.

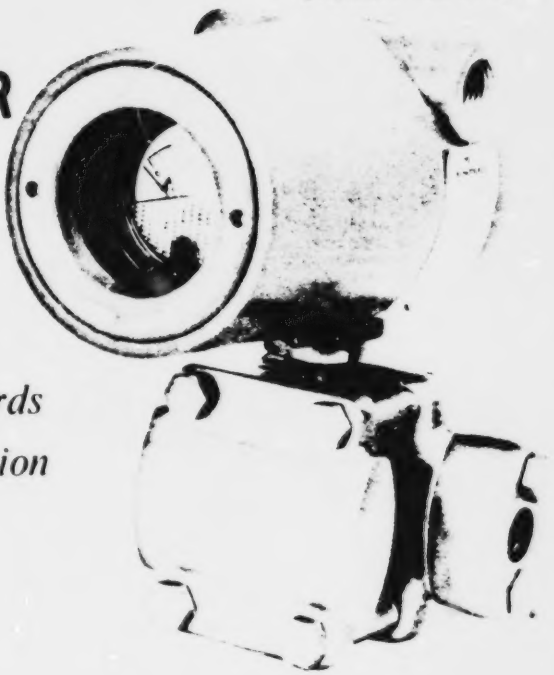
POST OFFICE BOX 35129 MINNEAPOLIS, MINNESOTA 55435

PHONE: (612) 941-5560 TWX: 910-576-3103 TELEX: 29-0183 CABLE: ROSEMOUNT

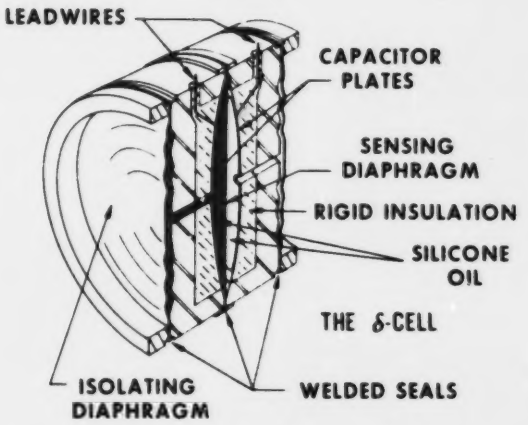
7/76

PRODUCT DATA SHEET 2260
(Replaces PDS 2110)

MODEL 1151GP ALPHALINE GAGE PRESSURE TRANSMITTER



Ranges from 5 in. H_2O to 6000 psig
Compatible with any 2-wire system
Solid state, plug-in printed circuit boards
Compact, rugged, impervious to vibration
External span and zero adjustments
0.25% accuracy
On 4–20 mA output:
- *Up to 600% elevation or 500% suppression*
- *Adjustable damping*



FEATURES

The ALPHALINE® Gage Pressure Transmitter* provides precision pressure measurement with zero based, elevated, or compound ranges. Vacuum can be measured by reversing the flanges and connecting to the low pressure side of the sensing element. Direct electronic sensing with the completely sealed δ-CELL™ capacitance sensing element eliminates mechanical force transfer and the associated problems with vibration and shock.

Installation and commissioning are simplified by compact design, 2-wire system compatibility, external span and zero adjustments and explosion-proof, weather-proof construction. Wiring terminals and electronics are in separate compartments, so the electronics remain sealed during installation. Reverse polarity protection keeps wiring mishaps from costing money. HASTELLOY C-276 and MONEL are available for corrosive service. Maintenance costs are reduced by the use of solid state plug-in printed circuit boards which are interchangeable among all Rosemount 1151 transmitters.

OPERATION

Process pressure is transmitted through an isolating diaphragm and silicone oil fill fluid to a sensing diaphragm in the center of the δ-CELL. The atmospheric reference pressure is transmitted in like manner to the other side of the sensing diaphragm. The displacement of the sensing diaphragm, a maximum motion of 0.004 inches, is proportional to the pressure differential across it. The position of the sensing diaphragm is detected by capacitor plates on both sides of the sensing diaphragm. The differential capacitance between the sensing diaphragm and the capacitor plates is converted electronically to a 2-wire, 4-20 mADC or 10-50 mADC signal.

Rosemount

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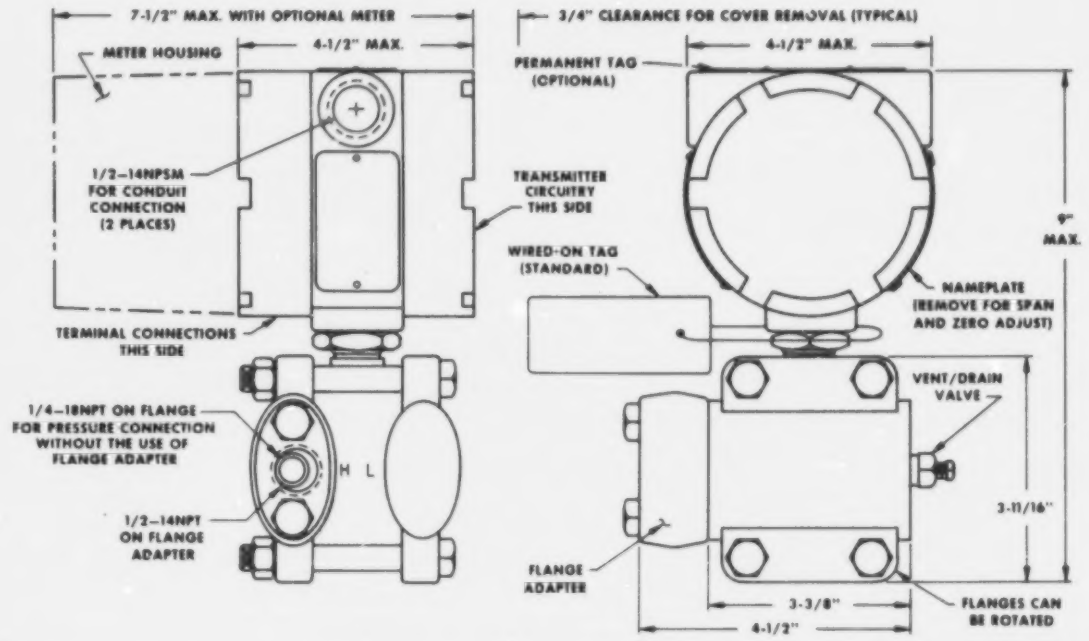
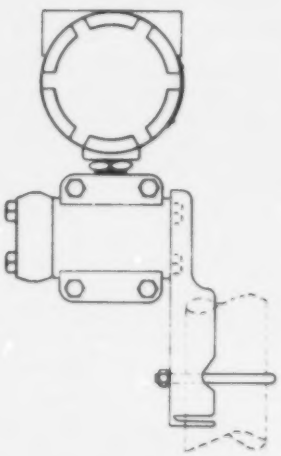
**Protected by one or more of the following U.S. Patents: No. 3,271,669; 3,318,153; 3,618,390; 3,646,538; 3,793,885; 3,800,413; 3,854,039; 3,859,594 and 3,195,028. Canada Patented 1968, 1974 and 1975. Patente Mexicana No. 118892. Other U.S. and Foreign Patents issued or pending.*

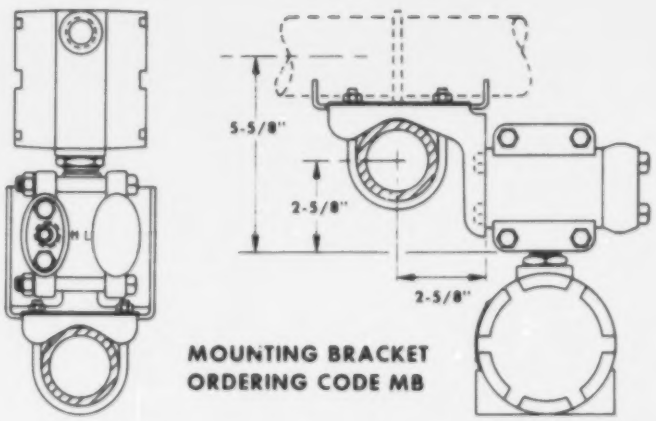
Dimensional Drawings



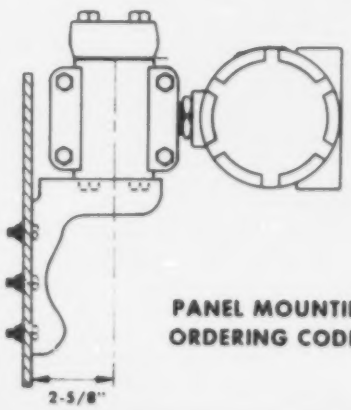
OPTIONAL MOUNTING BRACKETS FOR 2" PIPE SHOWN IN TYPICAL MOUNTING CONFIGURATIONS



FLAT MOUNTING BRACKET
ORDERING CODE FB



MOUNTING BRACKET
ORDERING CODE MB



PANEL MOUNTING BRACKET
ORDERING CODE PB

Functional Specifications

Service

Liquid, gas or vapor.

Ranges

0–5/30 in. H_2O (reverse flanges for vacuum)
0–25/150 in. H_2O (reverse flanges for vacuum)
0–125/750 in. H_2O (reverse flanges for vacuum)
0–17/100 psig
0–50/300 psig
0–170/1000 psig
0–500/3000 psig
0–1000/6000 psig

Outputs

4–20 mADC or 10–50 mADC.

Power Supply

External power supply required.
4–20 mADC: Up to 45 VDC.
Transmitter operates on 12 VDC with no load.
10–50 mADC: Up to 85 VDC.
Transmitter operates on 30 VDC with no load.

Load Limitations

See Figure 1.

Indication

Optional meter with 1¾", 0–100% scale. Indication accuracy is ±2% of span.

Hazardous Locations

Explosion proof: Approved by Factory Mutual for Class I, Division 1, Groups B*, C and D; Class II, Division 1, Groups E, F and G; and Class III, Division 1. Certification by Canadian Standards Association (CSA) for Class I, Groups C and D available as an option. **Intrinsically Safe:** FM certification optional for Class I, Division 1, Groups B, C and D when used with listed barrier systems.

Span and Zero

Continuously adjustable externally.

Zero Elevation and Suppression

Regardless of output specified, zero elevation and suppression must be such that neither the span nor the upper or lower range value exceed 100% of the upper range limit.
4–20 mADC Maximum zero elevation: 600% of calibrated span. Maximum zero suppression: 500% of calibrated span.
10–50 mADC Maximum zero elevation or suppression: 150% of calibrated span for ranges 3, 4 and 5; 50% of calibrated span for ranges 6, 7, 8, 9 and 0.

*Optional meter not approved for Group B.

Temperature Limits

–20° F to +200° F Amplifier operating.
–40° F to +220° F Sensing element operating.
–60° F to +250° F Storage.

Overpressure Limits

0 psia to 2000 psi for ranges to 1000 psig. 4500 psi for the 3000 psig range and 7500 psi for the 6000 psig range without damage to the transmitter. Operates within specifications for pressure above 1/2 psia. 10,000 psig proof pressure on flanges.

Humidity Limits

0–100% RH.

Volumetric Displacement

Less than 0.01 cubic inch.

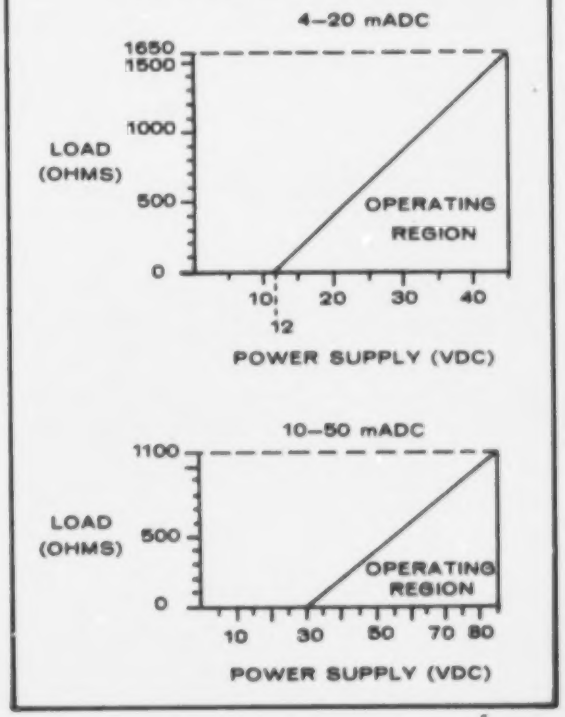
Damping

4–20 mADC: Time constant continuously adjustable between 0.2 and 1.67 seconds.
10–50 mADC: Time constant fixed at 0.4 second for range 3, 0.2 second for ranges 4 and 5, and 0.1 second for ranges 6, 7, 8, 9 and 0.

Turn-On Time

2 seconds. No warmup required.

FIGURE 1
LOAD LIMITATIONS



Performance Specifications

(ZERO BASED SPANS, REFERENCE CONDITIONS, 316SS ISOLATING DIAPHRAGMS)

Accuracy

±0.25% of calibrated span. Includes combined effects of linearity, hysteresis and repeatability.

Stability

±0.25% of upper range limit for six months.

Temperature Effect

At Maximum Span (e.g. 0–100 psig for 0–17/100 psig range)

Zero Error: ±0.5% of span per 100° F. Total effect including span and zero errors: ±1.0% of span per 100° F.

Note: Double the specified effect for range code 3.

At Minimum Span (e.g. 0–17 psig for 0–17/100 psig range)

Zero Error: ±3.0% of span per 100° F. Total effect including span and zero errors: ±3.5% of span per 100° F.

Note: Double the specified effect for range code 3.

Overpressure Effect

±0.25% of upper range limit for overpressure to the limit specified for the particular range.

Vibration Effect

±0.05% of upper range limit per g to 200 Hz in any axis.

Power Supply Effect

Less than 0.005% of output span per volt.

Load Effect

No load effect other than the change in power supplied to the transmitter.

Mounting Position Effect

Zero shift of up to 1 inch H_2O which can be calibrated out. No effect in plane of diaphragm. No span effect.

Physical Specifications

Materials of Construction †

Isolating Diaphragms and Drain/Vent Valves:
316SS, HASTELLOY C or MONEL.

Process Flange and Adapter:
Cadmium-plated Carbon Steel, 316SS, HASTELLOY C or MONEL.

Wetted O-Rings:
VITON.

Fill Fluid:
Silicone oil.

Bolting Flange and Bolts:
Cadmium-plated Carbon Steel.

Electronics Housing:
Low-copper aluminum (NEMA4)

Paint:
Baked acrylic enamel.

Process Connections

1/4 NPT on flange. 1/2 NPT on adapter.

Electrical Connections

1/2-inch conduit with screw terminals and integral test jacks compatible with miniature banana plugs (Pomona 2944, 3690 or equal).

Weight

12 pounds excluding options.

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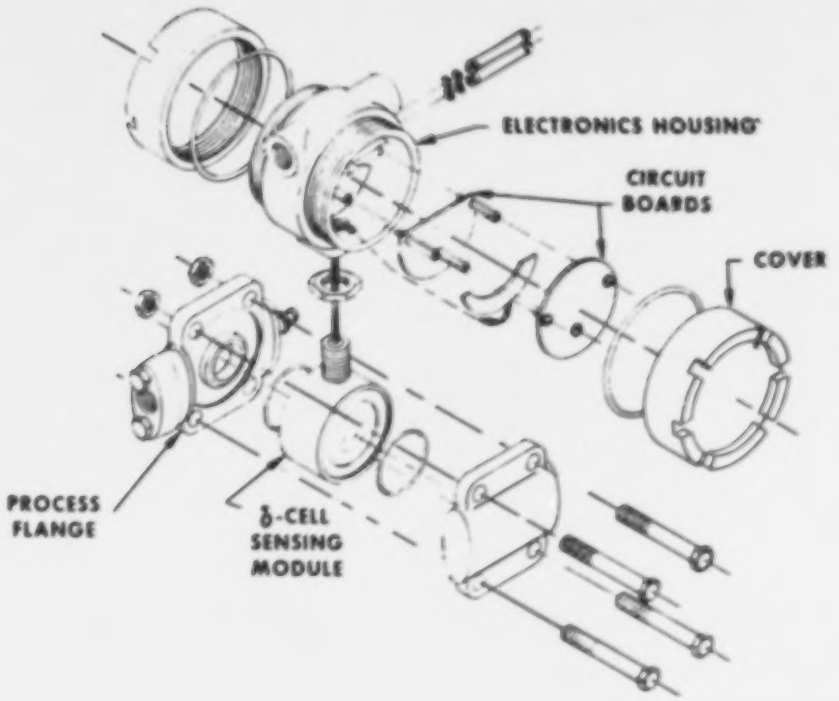
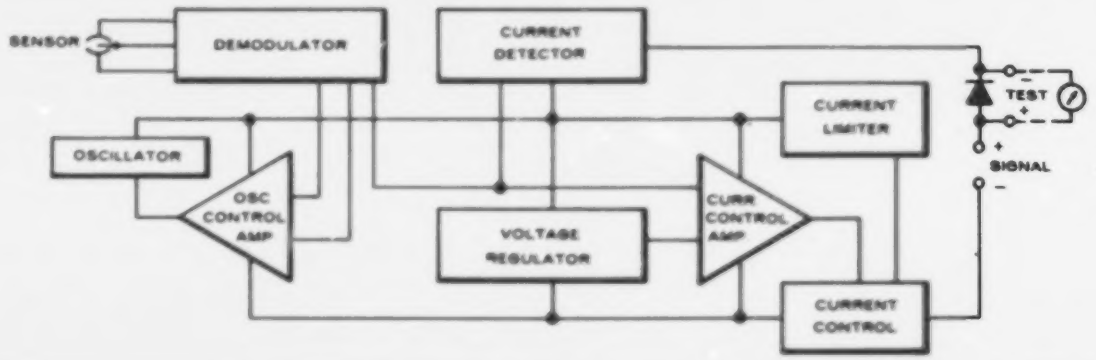
† MONEL is a trademark of International Nickel Co.
HASTELLOY is a trademark of the Cabot Corp.
VITON is a DuPont trademark.
Terminology per SAMA Standard PMC20.1-1973

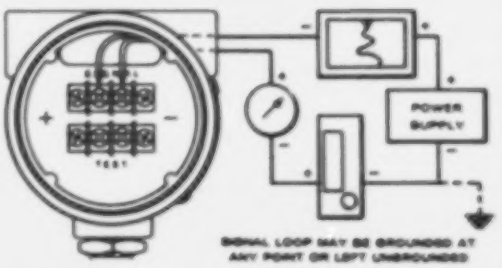
TYPICAL MODEL 1151 PRESSURE TRANSMITTER ASSEMBLY



Electrical Block Diagram



Wiring Connections



STANDARD ACCESSORIES All Models are shipped with flange adapter, vent/drain valve and one instruction manual per shipment.

TAGGING ALPHALINE Gage Pressure Transmitters will be tagged in accordance with customer requirements. All tags are stainless steel.

CALIBRATION Transmitters are factory calibrated to customer's specified span. If calibration is not specified, transmitters are calibrated at maximum range. Calibration is at ambient temperature and pressure.

Ordering Information

MODEL 1151GP	ALPHALINE GAGE PRESSURE TRANSMITTER

CODE	RANGES
3	0–5 to 0–30 inches H_2O (0–127 to 0–762 mm H_2O)
4	0–25 to 0–150 inches H_2O (0–635 to 0–3810 mm H_2O)
5	0–125 to 0–750 inches H_2O (0–3175 to 0–19050 mm H_2O)
6	0–17 to 0–100 psig (0–1.2 to 0–7.0 kg/cm^2)
7	0–50 to 0–300 psig (0–3.5 to 0–21 kg/cm^2)
8	0–170 to 0–1000 psig (0–12 to 0–70 kg/cm^2)
9	0–500 to 0–3000 psig (0–35 to 0–210 kg/cm^2)
0	0–1000 to 0–6000 psig (0–70 to 0–420 kg/cm^2)

1087 '2
1151GP 9E12B1C6
Andy Klenke

CODE	OUTPUT
E	4–20 mADC w/adjustable damping
B	10–50 mADC w/fixed damping

CODE	MATERIALS OF CONSTRUCTION		
	FLANGE AND ADAPTER	DRAIN/VENT VALVE	ISOLATING DIAPHRAGM
12	Cadmium Plated C.S.	316SS	316SS
13	Cadmium Plated C.S.	HASTELLOY C	HASTELLOY C-276
14	Cadmium Plated C.S.	MONEL	MONEL
22	316SS	316SS	316SS
23	316SS	316SS	HASTELLOY C-276
24	316SS	316SS	MONEL
33	HASTELLOY C	HASTELLOY C	HASTELLOY C-276
44	MONEL	MONEL	MONEL

CODE	OPTIONS
LM	Linear Meter, 0-100% scale
MB	Optional Mounting Bracket for Mounting to 2" Pipe
PB	Optional Mounting Bracket for Panel Mounting
FB	Optional Flat Mounting Bracket for Mounting to 2" Pipe
CE	Canadian Standards Association (CSA) Explosion Proof Certification for Class I, Groups C and D; Class II, Groups E, F and G; Class III; (Encl. IV).

INTRINSIC SAFETY APPROVAL (All Are Approved By Factory Mutual)

	OUTPUT CODES INCLUDED	BARRIER MANUFACTURER	BARRIER MODEL	CLASS I, DIVISION 1, GROUPS		
				B	C	D
F1	E	Foxboro	2AI-I2V-FGB	X	X	X
			2AI-I3V-FGB	X	X	X
F2	E	Taylor	124S1134	X	X	X
			124S1144	X	X	X
			124S931		X	X
			124S932		X	X
			124S1254		X	X
			124S1264		X	X
F3	E	Westinghouse	75SB01	X	X	X
			56FC12		X	X
F4	E	Leeds & Northrup	316569*	X	X	X
			316747*	X	X	X
F5	E	Fischer & Porter	805H023U01		X	X
			805H027U01		X	X
			805H027U02	X	X	X
F6	E	Fisher Controls	AC302		X	X
F7	E	Honeywell	*			

*Pending

1151GP–	6	E	12	LM, MB	← COMPLETED DESIGN SPECIFICATION

Rosemount Inc.

PHONE: (612) 941-5560 TWX: 910-576-3103 TELEX: 29-0183 CABLE: ROSEMOUNT

Revised 8/76

ENDEVCO® PRODUCT DATA

SERIES 8511

5 000 to 50 000 psi
High resonance frequency

PIEZORESISTIVE PRESSURE TRANSDUCERS

TEMPORARILY OUT OF PRINT

The Endevco Model 8511 is a rugged, piezoresistive pressure transducer for high pressures. It has a ⅜ in. mounting thread and is available in ranges from 5 000 to50 000 psig. It offers high shock resistance, high overload capability, and low photosensitivity.

Endevco pressure transducers feature a four-active arm strain gage bridge diffused into a sculptured silicon diaphragm for maximum sensitivity and wideband frequency response. Self-contained hybrid temperature compensation provides stable performance over the wide temperature range of 0 to 200°F (-18 to +93°C). Endevco transducers also feature excellent linearity (even to 3x range), high shock resistance, and high stability during temperature transients.

The Model 8511 is widely used for high pressure applications such as studies of structural loading by shock waves resulting from explosive blasts, pulsations in hydraulic systems, and combustion problems. It features an ablative coating over the diaphragm to protect against particle impingement.

ACTUAL SIZE

SPECIFICATIONS FOR THE 8511 SERIES

(According to ANSI and ISA Standards)

PERFORMANCE	8511-5K	8511-10K	8511-20K	8511-50K
RANGE (psig) (1 psi = 6.895 kPa)	5 000	10 000	20 000	50 000
SENSITIVITY[1] (mV/psi at 10.00 Vdc)	0.10 ±0.030	0.050 ±0.015	0.025 ±0.008	0.010 ±0.003
RESONANCE FREQUENCY[2] (kHz)	>500	>500	>500	>500
LINEARITY				
Independent (±__% of FSO, 0 to FSO)	0.3	0.6	0.4	0.5
Independent at 3x overrange (±__% of 3x FSO)	0.3	0.8	1.0	Note[3]
HYSTERESIS (% of FSO)	0.3	0.8	0.2	0.5
REPEATABILITY (±__% of FSO)	0.1	0.5	0.1	0.5
COMBINED LINEARITY AND HYSTERESIS (RSS maximum, % of FSO)	1.2	1.5	1.2	2.0
ZERO MEASURAND OUTPUT (±__mV)	10.0	10.0	10.0	10.0
ZERO SHIFT				
At 3x Overrange (±__% of 3x FSO)	0.1	0.2	Note[4]	Note[3]
With Mounting Torque at 15 lbf·in (±__% of FSO)	0.1	0.1	0.1	0.1 @ 25 lbf·ft
At Maximum Temperature[5] (±__% of FSO, ref. 75°F)	3.0	3.0	3.0	3.0
SENSITIVITY SHIFT				
At Maximum Temperature[5] (±__% of FSO, ref. 75°F)	4.0	4.0	4.0	4.0
THERMAL TRANSIENT RESPONSE (psi/°F) (per ISA-S37.10, Para. 6.7, Proced. 1)	1.1	1.5	0.4	0.1
WARMUP TIME (seconds)	15	15	15	15
ACCELERATION SENSITIVITY[2]				
Longitudinal (psi/g)	0.003	0.004	0.008	0.003
Lateral (psi/g)	0.001	0.002	0.004	0.003
BURST PRESSURE				
Diaphragm (±__psi)	20 000	30 000	40 000	75 000

[1]The unit is calibrated at 10.00 Vdc excitation. Operation of the unit at voltages other than 10.00 Vdc requires that the unit be calibrated at that voltage. Endevco Model 4422 or 4470 Signal Conditioner is recommended as the excitation source.

[2]Improved performance can be obtained by removal of the ablative coating on the diaphragm.

[3]Overrange is limited to 75 000 psi. A shift in calibration may occur after exposure to pressures above 50 000 psi.

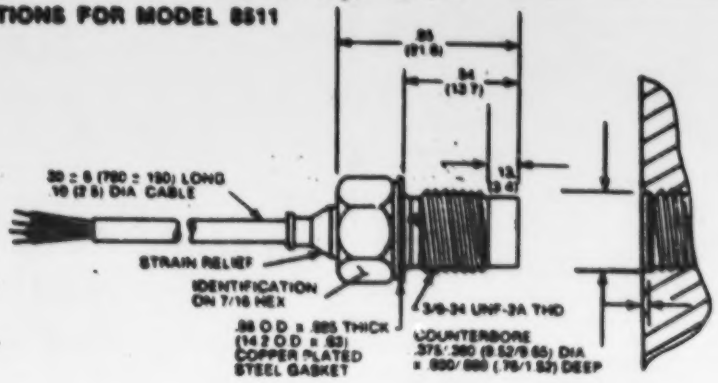
[4]Overrange is limited to 40 000 psi. Zero shift at 2x range is typically ±1% of 3x FSO.

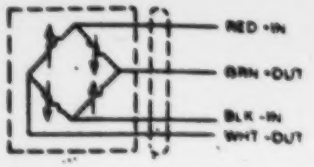
[5]Tighter specifications available on special order.

NOTE: All values are typical over the compensated temperature range except where noted.

Endevco cautions the user that this product has not been clinically tested for medical applications, and no claim has been made for sterility, nonpyrogenicity, lack of reactivity or electrical safety.

SPECIFICATIONS FOR MODEL 8511


.85 (21.6)
.54 (13.7)
.13 (3.4)
30 ± 6 (760 ± 150) LONG
10 (2.5) DIA CABLE
STRAIN RELIEF
IDENTIFICATION ON 7/16 HEX
.88 O.D. x .005 THICK (14.2 O.D. x .03) COPPER PLATED STEEL GASKET
3/8-24 UNF-2A THD
COUNTERBORE .375/.380 (9.52/9.65) DIA x .930/.980 (.76/1.52) DEEP



DIMENSIONS IN INCHES AND (MILLIMETRES)

ELECTRICAL	ALL MODELS
EXCITATION	
Rated	10.00 Vdc
Maximum	18 Vdc
ELECTRICAL CONFIGURATIONS	Four-active-arm piezoresistive bridge
POLARITY	Positive output for increasing pressure
RESISTANCE	
Input	1 000 Ω
Output	1 300 Ω
Isolation (ambient conditions)	>100 MΩ at 50 V
PHYSICAL	
DEAD VOLUME	0.0003 in.³ (0.0049 cm³)
MOUNTING	Threaded case, 3/8-24 UNF-2A threaded length 0.520 in
MOUNTING TORQUE	12 ±2 lbf·ft to 20 000 psi 25 ±2 lbf·ft above 20 000 psi 1 lbf·ft = 1.356 N·m
MATERIAL	
Case	Stainless steel
Exposed to Measured Fluid*	Case, Parylene C, epoxy, copper gasket, ablative
CABLE	Integral, 4-conductor, shielded, Teflon-insulated 32 AWG (7/40) silver plated copper conductors, gray PVC jacket, 30 in. (0.76 m) long
IDENTIFICATION	8511-XX, where XX denotes rated pressure in psig
WEIGHT	0.4 oz. (11 g) less cable

ENVIRONMENTAL	
TEMPERATURE RANGE	
Compensated	0°F to 200°F (-18°C to +93°C). Can be compensated over any 200°F (110°C) span from -65°F to +225°F on special order
Maximum	-65°F to +250°F (-54°C to +121°C)
VIBRATION	1 000 g, sinusoidal
SHOCK	20 000 g, 100 μs, half-sine
HUMIDITY (per MIL-STD-202E, Method 103B, Test Condition B)	Isolation resistance greater than 100 MΩ at 50 V. External case is sealed with epoxy. Circuit within case, vented through tube, is coated with Parylene C.

*Designed for use with dry non-conductive gases. Not suitable for use with high pH or low pH liquids, long term exposure to water, or exposure to solvents which may attack epoxies.

Continued product improvement necessitates that Endevco reserve the right to modify these specifications without notice.

RELIABILITY: Endevco maintains a program of constant surveillance over all products to ensure a high level of reliability. This program includes attention to reliability factors during product design, the support of stringent Quality Control requirements, and compulsory corrective action procedures. These measures, together with conservative specifications, have made the name Endevco synonymous with reliability. Endevco's Quality and Reliability System meets the requirements of MIL-Q-9858A and MIL-STD-785A.

CALIBRATION. Each transducer is calibrated at room temperature for pressure sensitivity with 10.00 Vdc excitation. Special calibrations available—consult factory.

U.S. Patent Nos. 4 085 970 and 4 093 933 apply to this transducer.

ENDEVCO

RANCHO VIEJO ROAD • SAN JUAN CAPISTRANO, CA 92675 • TELEPHONE (714) 493 8181

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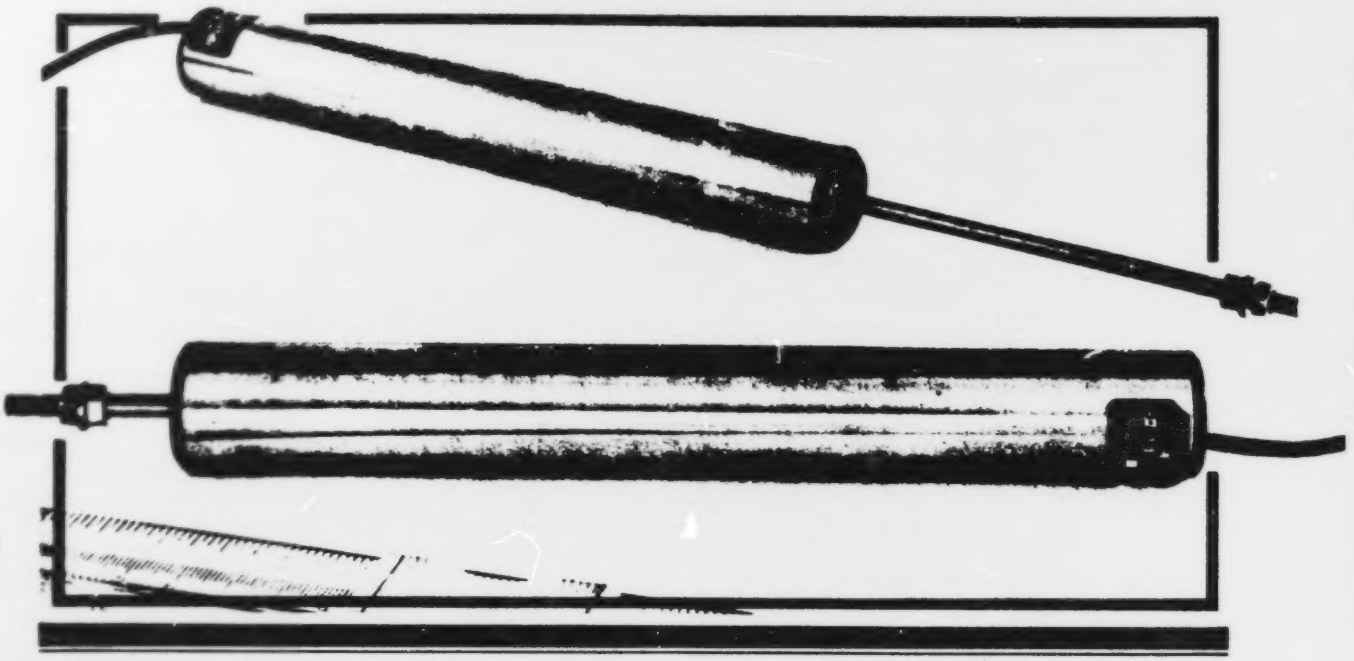
TWX 910-595-1413 TELEX 66-5609

PRINTED IN USA REV 7/81

data sheet SE

SE353,354 Long Stroke DC/DC Displacement Transducers



◯ Displacements up to ± 300mm ◯ High Accuracy ◯ Infinite Resolution ◯ High Output
◯ Completely Sealed Unit ◯ Stainless Steel Case

Introduction

The long stroke dc/dc transducer is an inexpensive device which can be used to measure linear displacements up to ± 250mm with high accuracy and infinite resolution. When connected to a stabilised dc supply of nominally 12 volts (minimum 9 volts; maximum 15 volts) the transducer produces a dc output signal which varies proportionally to the linear displacement of its armature. The output signal is polarised, movements of the armature in one direction produces a positive dc output signal and movements in the opposite direction will produce a negative dc output signal. The maximum output voltage for full rated stroke is nominally ± 2 volts and the transducer source impedance is 2K Ω. The maximum output signal current is approximately 0.5 milliamp within the stated accuracy limits and occurs when the transducer is connected to external load of 1K. The output signal is suitable for direct connection to suitable moving coil indicators, moving coil recorders (ultra violet and direct writing) potentiometric recorders, digital voltmeters and data loggers. Zero and span conditioning is available.

The dc/dc transducer is a completely sealed unit within a stainless steel case. Five ranges of long stroke transducers are manufactured viz ± 15mm ± 25mm ± 50mm ± 150mm and ± 250mm. The transducers can be calibrated over a shorter stroke if required for better optimum accuracy. The armature is manufactured from high permeability magnetic material which is mounted on a ceramic carrier rod. Two basic models are required.

SE TYPE 353 – Free guided armature with *'Delrin' bearings for minimum friction.

SE TYPE 354 – Captive spring return with guided armature in 'Delrin' bearings for minimum friction.

NOTE: TYPE 354 is not available on ± 250mm,± 300mm transducers.

Specification

Excitation (d.c. volts)
Nominal 12
Minimum 9
Maximum 15

Nominal Current Consumption (mA at 10 volts)
± 15 mm 25mA
± 25 mm 50mA
Others 40mA

Linearity (of total stroke) 0.3

Nominal Sensitivity 400mV/V/total stroke

Output Ripple (peak to peak) 0.15%

Bandwidth (3dB point) 0-200Hz

Operating Temperature Range -20°C to +80°C

Storage Temperature (maximum) +125°C

Temperature Co-ef
(zero shift) Less than 0.015% of stroke per °C
(sensitivity) Less than 0.025% of stroke per °C

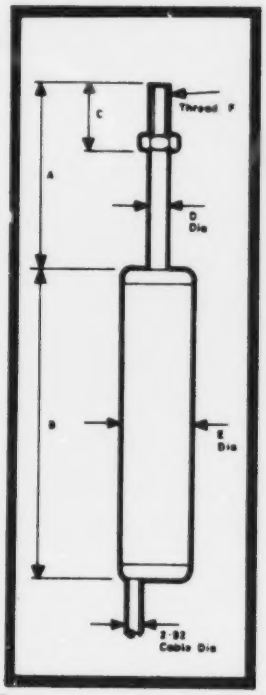
Source Impedance 2.0KΩ

Calibration Load 20.KΩ

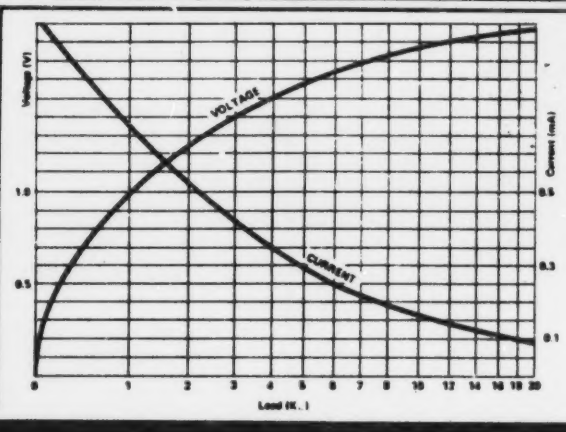
Cable 3 metres of 5 core P.V.C.

* SE353 also available in ± 300mm range.

Type	Nominal Stroke	Units	A	B	C	D	E	F	Max Travel	Weight (gm) Body	Weight (gm) Core	Spring (gm) Force	Spring (gm) Pre-ld
353	± 15 mm ± 0.5 in	mm ins	44.5 1.75	97.5 3.85	15 .59	3.17 .12	19 .75	M3 6BA	± 28 ± 1.1	60	7	1.85 gm/mm	30
	± 25 mm ± 1 in	mm ins	70 2.76	203 7.99	19 .75	4.75 .19	25.4 1	M5 2BA	± 43 ± 1.69	320	21	2.68 gm/mm	85
	± 50 mm ± 2 ins	mm ins	95 3.74	324 12.76	19 .75	4.75 .19	25.4 1	M5 2 BA	± 71 ± 2.8	450	28	1.73 gm/mm	170
	±150mm ± 5 ins	mm ins	197 7.76	629 24.76	1 9 .75	4.75 .19	25.4 1	M5 2BA	±178 ± 7.01	910	80	1.18 gm/mm	230
	± 250mm ± 10 ins	mm ins	298 11.73	705 27.76	19 .75	4.75 .19	25.4 1	M 5 2BA	± 279 ±10.98	1400	112	—	—



Type	Nominal Stroke	Units	A	B	C	D	E	F	Max. Travel	Weight (gm) Body	Weight (gm) Core	Spring (gm) Force	Spring (gm) Pre-ld
354	± 15mm ± 0.5 in	mm ins	44.5 1.75	97.5 3.85	15 .59	3.17 .12	19 .75	M3 6 BA	± 28 ± 1.1	60	7	1.85 gm/mm	30
	± 25mm ± 1.0 in	mm ins	70 2.76	203 7.99	19 .75	4.75 .19	25.4 1	M5 2 BA	± 43 ±1.69	320	21	2.68 gm/mm	85
	± 50mm ± 2.0 ins	mm ins	95 3.74	324 12.76	19 .75	4.75 .19	25.4 1	M5 2 BA	± 71 ± 2.8	450	28	1.73 gm/mm	170
	±150 mm ± 50 ins	mm ins	197 7.76	629 24.76	19 .75	4.75 .19	25.4 1	M 5 2 BA	±178 ±7.01	910	80	1.18 gm/mm	230



Graphs to show variation of output voltage and load current for a variation in load using a ± 50 mm transducer. This result is typical for the range of long stroke transducers.

*'Delrin' an acetal plastic manufactured by Du Pont (U.K.) Ltd.
Having the outstanding properties of being exceptionally strong ,stiff, tough and very resistant to organic solvents. The moisture absorption is very low & dimensional stability exceptional.

ELECTRICAL CONNECTIONS:-

Red	—	**+VE Energising Supply**
Blue	—	**-VE Energising Supply**
Green	—	**Output**
Yellow, Black or White	—	**Output**

The company reserves the right to alter these designs and specifications without notice.

Specification

Excitation (d.c. volts)
Nominal 12
Minimum 9
Maximum 15

Nominal Current Consumption (mA at 10 volts)
± 15 mm 25mA
± 25 mm 50mA
Others 40mA

Linearity (of total stroke)
0.3

Nominal Sensitivity 400mV/V/total stroke

Output Ripple (peak to peak) 0.15%

Bandwidth (3dB point) 0-200Hz

Operating Temperature Range -20°C to +80°C

Storage Temperature (maximum) +125°C

Temperature Co-ef
(zero shift) Less than 0.015% of stroke per °C
(sensitivity) Less than 0.025% of stroke per °C

Source Impedance 2.0K Ω

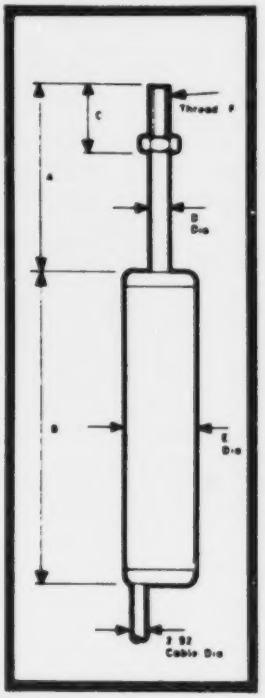
Calibration Load 20.K Ω

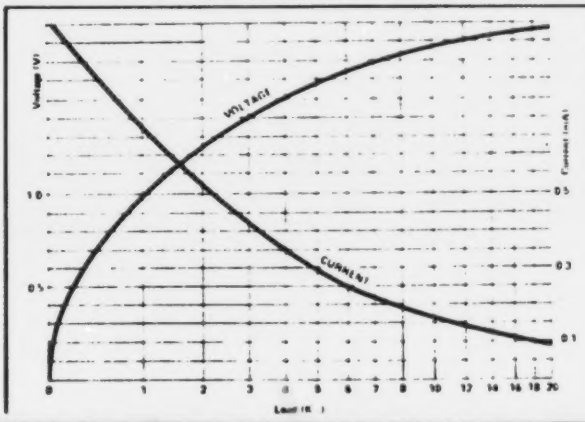
Cable 3 metres of 5 core P.V.C.

* SE353 also available in ± 300mm range.

Type	Nominal Stroke	Units	A	B	C	D	E	F	Max Travel	Weight (gm) Body	Weight (gm) Core	Spring (gm) Force	Spring (gm) Pre-ld
353	± 15 mm ± 0.5 in	mm ins	44.5 1.75	97.5 3.85	15 .59	3.17 .12	19 .75	M3 6BA	± 28 ± 1.1	60	7	1.85 gm/mm	30
	± 25 mm ± 1 in	mm ins	70 2.76	203 7.99	19 .75	4.75 .19	25.4 1	M5 2BA	± 43 ± 1.69	320	21	2.68 gm/mm	85
	± 50 mm ± 2 ins	mm ins	95 3.74	324 12.76	19 .75	4.75 .19	25.4 1	M5 2 BA	± 71 ± 2.8	450	28	1.73 gm/mm	170
	±150mm ± 5 ins	mm ins	197 7.76	629 24.76	1.9 .75	4.75 .19	25.4 1	M5 2BA	±178 ± 7.01	910	80	1.18 gm/mm	230
	± 250mm ± 10 ins	mm ins	298 11.73	705 27.76	19 .75	4.75 .19	25.4 1	M5 2BA	± 279 ±10.98	1400	112	--	--

Type	Nominal Stroke	Units	A	B	C	D	E	F	Max. Travel	Weight (gm) Body	Weight (gm) Core	Spring (gm) Force	Spring (gm) Pre-ld
354	± 15mm ± 0.5 in	mm ins	44.5 1.75	97.5 3.85	15 .59	3.17 .12	19 .75	M3 6 BA	± 28 ± 1.1	60	7	1.85 gm/mm	30
	± 25mm ± 1.0 in	mm ins	70 2.76	203 7.99	19 .75	4.75 .19	25.4 1	M5 2 BA	± 43 ±1.69	320	21	2.68 gm/mm	85
	± 50mm ± 2.0 ins	mm ins	95 3.74	324 12.76	19 .75	4.75 .19	25.4 1	M5 2 BA	± 71 ± 2.8	450	28	1.73 gm/mm	170
	±150 mm ± 50 ins	mm ins	197 7.76	629 24.76	19 .75	4.75 .19	25.4 1	M5 2 BA	± 178 ±7.01	910	80	1.18 gm/mm	230





Graphs to show variation of output voltage and lead current for a variation in load using a ± 50 mm transducer. This result is typical for the range of long stroke transducers.

* 'Delrin' an acetal plastic manufactured by Du Pont (U.K.) Ltd. Having the outstanding properties of being exceptionally strong, stiff, tough and very resistant to organic solvents. The moisture absorption is very low & dimensional stability exceptional.

ELECTRICAL CONNECTIONS:-

Red	—	+VE Energising Supply
Blue	—	-VE Energising Supply
Green	—	Output
Yellow, Black or White	—	Output

The company reserves the right to alter these designs and specifications without notice

SE Labs (EMI) Ltd North Feltham Trading Estate, Feltham, Middlesex. Telephone: 01-890-1166 Telex 23995
Northern Sales Office, Bessel Lane, Stapleford, Nottingham. Telephone: Sandiacre 7255

EMI One of the EMI Group of companies

BULLETIN #363-3

STRAINSERT
Standard Internally Gaged
HEX HEAD CAP SCREWS
(STEEL ALLOY)

To Measure
accurate preload,
service load and overload
of bolted assemblies

For Maximum
uniformity, efficiency
and reliability
in bolted assemblies

For Effective
research, testing
and manufacture
of bolted assemblies

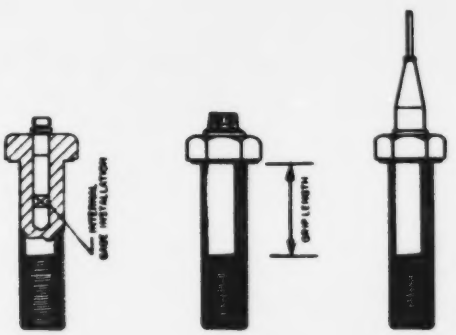
Strainsert fasteners utilize an exclusive internal gaging method* to indicate bolt tension due to preload and subsequent service loads with strain gage accuracy. They are the first fasteners to provide a means for accurate, independent inspection of an assembled bolt for preload, thereby enhancing the structural integrity and reliability of both the bolt and the assembly.

The gaging process consists of the installation of foil type bonded strain gages in a small hole drilled along the longitudinal neutral axis of the bolt. This method compares favorably in accuracy and stability with the best external gage installations, but it is vastly superior to external installations in mechanical and environmental ruggedness and miniaturization since the internal strain gage installation is self-protecting.

Neither the gage nor the drilled hole reduce the allowable bolt load in a Strainsert fastener. The gage installation will withstand and accurately indicate the full allowable load of the highest strength bolts available. Hole depth is confined to the grip length of the bolt, and the hole diameter is controlled so that the bolt cross-section through the threads is smaller than the section through the shank with the gage hole.

Standard hex head cap screws are available in three types, based on provisions for lead wires:

LEAD WIRE TERMINATIONS



Type C with Connector | Type H with Multi-pin Header | Type W with Cable

Type C: with screw type miniature connector, requiring mating cable assembly

Type H: with multi-pin header, for soldered lead wire connections

Type W: same as Type H, with 4-ft. factory-installed cable.

Over 250 different Strainsert Hex Head Cap Screws are stocked. Delivery is two weeks or less, f.o.b. Bryn Mawr, Pennsylvania. For specific sizes available, ask for the Price and Stock List on Internally Gaged Hex Head Cap Screws. For a more complete description of internal gage installations in bolts and studs ask for Strainsert Bulletin #361-5.

*U.S. Patent #2,873,341

STRAIN Stock Internally Gaged HEX HEAD CAP SCREWS

STEEL (SAE Grade 8 or Better)

MECHANICAL SPECIFICATIONS

Material	SAE 4140 or equivalent.
Hardness	Rockwell C32 to C38.
Ultimate Tensile Strength	150,000 psi Minimum; 160,000 psi average.
Threads	Class 2A, rolled
Thread length	2-diameters + ¼ inch full threads + 3/16 inch maximum imperfect threads.
Finish	Cadmium or chrome plated.

ELECTRICAL SPECIFICATIONS

ITEM	CHARACTERISTIC
GAGES	Metal Foil
GAGE FACTOR	2.00
SERVICE TEMPERATURE	150°F or 300°F
LINEARITY	± 1% of Allowable Load
REPETITION	± 0.1%
RESISTANCE	120 ± 2 or 350 ± 5 ohms
CONFIGURATION	Quarter- (QB), Double Quarter- (DQB), or Full-Bridge (FB)
ACTUAL STRAIN	2400 $\mu\varepsilon$ (design center)
OUTPUT SIGNAL (nominal, at allowable load)	FB: 3.1 mv/v
	DQB: 2.4 mv/v
	QB: 1.2 mv/v
EXCITATION	120-ohm QB: 6V Across Gage
	350-ohm QB: 12V Across Gage
	120-ohm DQB: 6V Across Bridge
	350-ohm DQB: 12V Across Bridge
	120-ohm FB: 6V Across Bridge
	350-ohm FB: 12V Across Bridge

ALLOWABLE SCREW LOADS

Allowable screw loads for Strainsert Hex Head Cap Screws, as tabulated below, are based on approximately 70% Yield Strength of the threads, in pounds.

SCREW DIA.	FINE THDS.	COARSE THDS.
¼	2,400	2,400
5/16	4,800	4,200
3/8	7,200	6,300
7/16	10,200	8,700
½	13,200	12,000
9/16	16,800	15,000
5/8	21,900	19,200
¾	32,100	28,200
7/8	44,000	38,600
1	59,200	52,000
1⅛	73,600	65,000
1¼	93,600	81,000
1½	150,000	120,000

Each cap screw is proof-loaded to above indicated load or 30,000-lbs., whichever is smaller, as part of quality control procedure. Both the value of proof-load and actual micro-strain output signal obtained are furnished to customer on a no-charge basis.

Your Strainsert Representative:

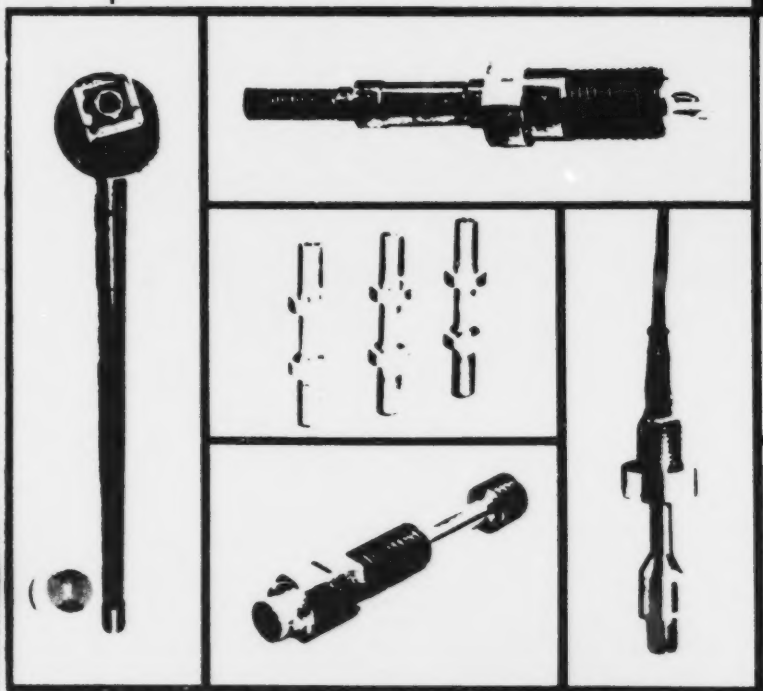
STRAINSERT COMPANY 24 Summit Grove Avenue, Bryn Mawr, Pennsylvania 19010, Telephone (215) 525-0685

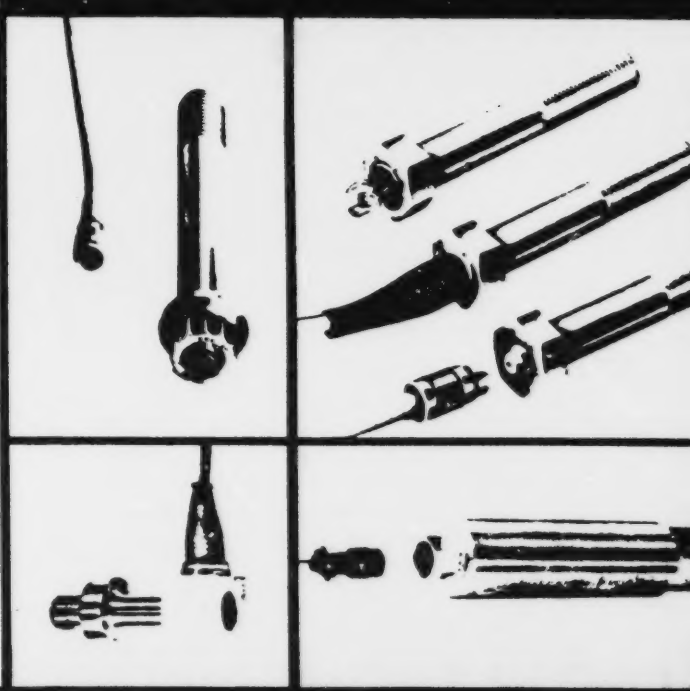
Printed in U.S.A.

STRAINSERT
Custom Load-Sensing BOLTS & STUDS

Strainsert Bolts and Studs, with built-in strain gages, permit:

- measurement of loads induced in fasteners
- accurate tightening of fasteners within 1% of induced load
- uniform tightening of fasteners in a bolt pattern
- overload detection in bolted machinery
- use of fasteners as load-link transducers
- quarter-, double quarter-, and full-bridge configurations





HOW STRAINSERT BOLTS AND STUDS CAN BE APPLIED

- Fasteners can be accurately tightened and the preload measured to a tolerance of better than 1% of the maximum load. In the past, the only possible method of measuring load was with a torque wrench. The accuracy of a torque wrench in the hands of an experienced operator is, at best, ± 20%.

- Bolted equipment can be inspected after assembly. There is no practical method — except with internally gaged bolts — to measure preload on a tightened bolt.

- Internally gaged fasteners strategically placed in equipment can act as built-in sensors for overload detection.

- Assemblies can be monitored and inspected under simulated or actual service conditions to see if any external forces exceed the preload. Overloads due to vibration, shock, etc. can be easily measured at any time during the life of the assembly.

- Very accurate analysis of bolt loading can be made over a continuous time period. In applications of this type, internally gaged bolts become a new basic research tool.

- Gaged bolts and studs can be used as inexpensive load cells.

STRAINSERT FASTENERS OFFER:

- **Bolts with Full Load Carrying Capacity** — Bolts with Strainsert internal gage installations have the full load carrying capacity of the original ungaged bolt. Cross-sectional area of the threaded portion of a full shank bolt is always smaller than the cross sectional area of the shank. The difference in areas permits a hole to be drilled in the shank for the gage installation without weakening the bolt.

- **Guaranteed Accuracy** — Giving precise calibration and accuracy guarantees for Strainsert Bolts and Studs is not a simple matter. Most gage installations are in fasteners supplied by the customer or purchased from the fastener manufacturers. Consequently, there is no control over the fastener material, design or quality.

  For this reason, we guarantee Strainsert Bolts and Studs to have a combined error due to repetition, nonlinearity and hysteresis of less than 1% of maximum load. Actually, the combined error is usually less than ½%.

- **Proof-Loading of Gage Installations** — Prior to shipment, all gage installations are proof-loaded as part of the quality control procedure. Unless otherwise specified, bolts are loaded to approximately 70% of yield and studs to the design value, neither to exceed 30,000 lbs. Loading is done in a dead weight device and both the actual proof load and the corresponding strain reading or signal are furnished to the customer free of charge. A proof load of the customer's preference will be used whenever specified.

INTERNAL GAGE INSTALLATIONS

Gages installed in Strainsert Bolts and Studs are foil type, electric resistance strain gages. They are bonded and sealed in a small hole along the longitudinal neutral axis of the bolt. The hole is then filled with an inert plastic material. After installation the gages are practically immune to physical, chemical and environmental damage.

Internal gage installations by Strainsert are as good as the very best external gage installations. The patented installation technique conforms to the best recommendations of gage and cement manufacturers.

Actually, there are reasons to expect the performance of an internal gage installation to be superior to conventional external installations. For one thing, gages in a full-bridge internal installation are located very close to each other and are bound to be in a uniform temperature environment.

GAGE CONFIGURATION COMPENSATES FOR BENDING AND TORQUE

Quarter-bridge installations consist of two gages in series mounted 180 degrees apart on the circumference of the hole with the grid in an axial direction. This arrangement provides the best indication of bolt load and also helps compensate for bending and torque. To eliminate lead-wire temperature effects, a three-wire lead system is used. Trim resistors or other compensations are not furnished with quarter- and double quarter-bridge gage installations.

Double quarter-bridge installations are similar to quarter-bridge, except the two gages are independently wired. Four lead wires are used. The output signal is twice that of the quarter-bridge circuit. External bridge completion circuits are required for both the quarter- and double quarter-bridges.

Full-bridge internal gage installations are made in the same size holes as for quarter-bridge. They are wired as shown with axial active gages and circumferential complementary gages. Trims and compensations are offered only if there is room for the necessary components.

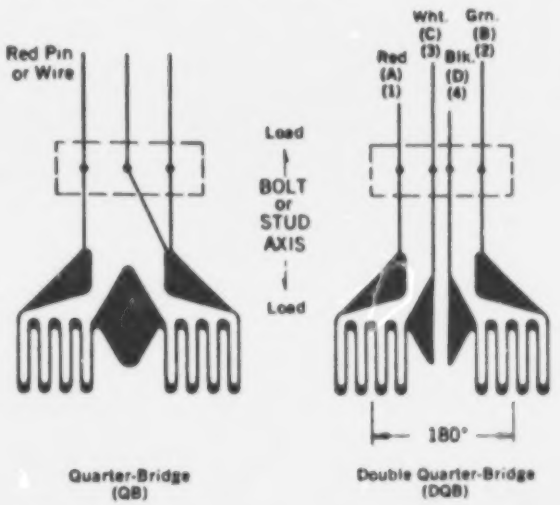
FUNCTIONAL DIFFERENCE BETWEEN A BOLT AND STUD

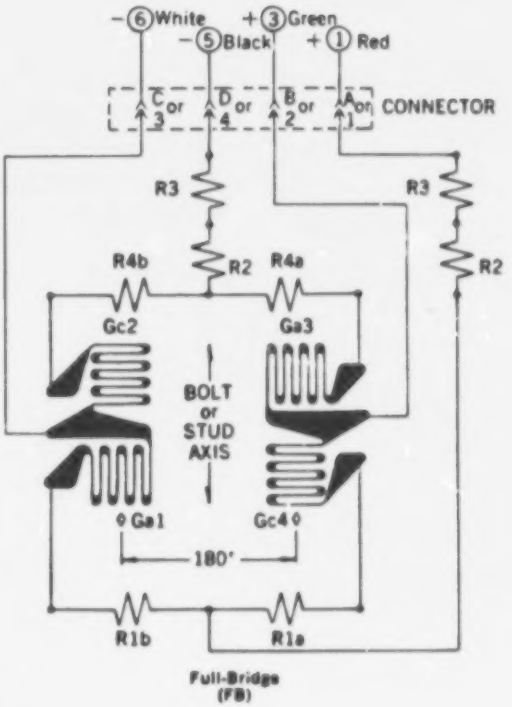
When a bolt is tightened, a preload is induced in the shank. For the bolt to function properly, the preload should be greater than all externally applied loads. If the preload is not greater than the external load, the bolt will be subject to fatigue and will usually fail.

A Strainsert Bolt will sense preload and forces greater than preload. It cannot, however, sense external forces which are smaller than preload since they do not put any additional strain on the bolt. With a stud, tightening the threads does not necessarily preload the shank. Therefore, a Strainsert Stud can be used as a normal transducer, without the bolt preload complications described above.

It is important to keep this distinction between bolts and studs in mind when making force or load measurement. This is particularly true with simple studs such as those in Figure A (page 4) and Strainsert Standard Studs (see Brochure #364-1), since they can function either as a bolt or stud depending on the application.

INTERNAL GAGE WIRING DIAGRAMS





LEGEND

Ga: Active Gage

Gc: Complementary Gage

Excitation: +1 and −5
Signal: +3 and −6
} Numbers correspond to Model HW1-D Strain Indicator terminals.

BRIDGE TRIM RESISTORS

Initial Zero Load Balance: R1a or R1b

Signal Trims: R2

Modulus Trims: R3

Zero Load Temp. Compensation: R4a or R4b

LEAD WIRE TERMINATIONS

Three basic lead wire terminations are available for bolts and studs.

Type C — a separable connector

Type H — a multi-pin header for soldered lead wire connections

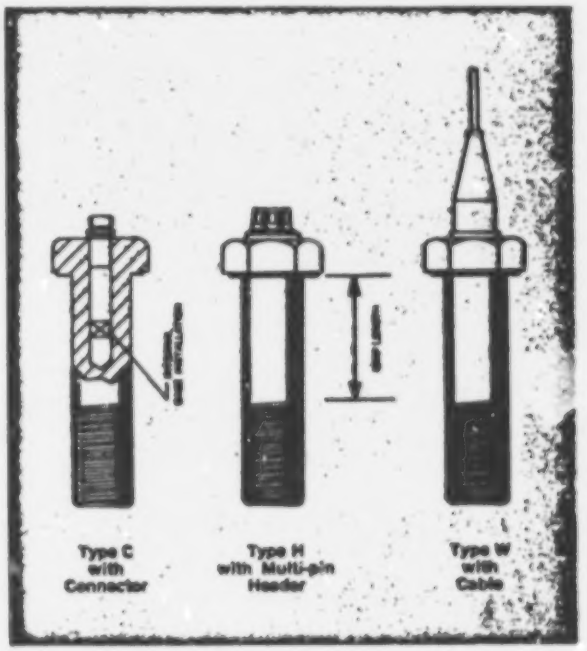
Type W — a Type H bolt with factory installed cable

Quarter-, double quarter-, and full-bridge internal gage installations can be made in bolt sizes down to #10 diameter.

All the above three types of lead wire terminations are available on bolts of ¼-inch diameter and larger.

Number 10 screws are available as Type H or Type W only.

Lead wire configurations for smaller size studs depend on size. See price and stock list for a guide to the SJ Series Studs.



BOLT GRIP LENGTH REQUIREMENTS

For proper performance the gage installation in a bolt should be below the head in the unthreaded section of the shank. This is the point where strain is most representative of bolt load. Minimum grip lengths recommended for various bolt sizes are shown below.

BOLT DIA (inches)	#10	¼	5/16	3/8	7/16	½	9/16	5/8
MIN GRIP LENGTH (inches)	½	⅞	1	1	1	1 1/16	1 1/8	1 1/16

BOLT DIA (inches)	¾	⅞	1	1 1/8	1 ¼	1 ⅜	1 ½	-
MIN GRIP LENGTH (inches)	1 ⅜	1 ½	1 ⅝	1 ¾	2	2 ¼	2 ½	-

Bolts with shorter grip lengths are gaged on special order

STRAINSERT Custom Load-Sensing BOLTS & STUDS

STRAINSERT STUDS ARE AVAILABLE IN MANY SHAPES

The shape and geometry of a Strainsert Stud can take many forms. A few of the common configurations are shown below.

Very often studs are designed by the customer and include all the details required by a specific application. In such cases, the recommended hole sizes for which Strainsert Company is set up to make quarter-, double quarter-, and full-bridge gage installations are:

- #37 (.104-in. dia.) 5/32-in. diameter
- #9 (.196-in. dia.), and 1/4-in. diameter

A Few Common Stud Configurations:

Figure A

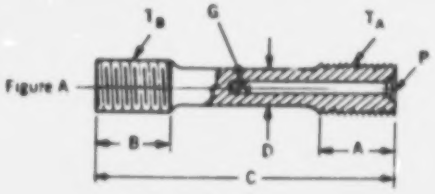


Figure B

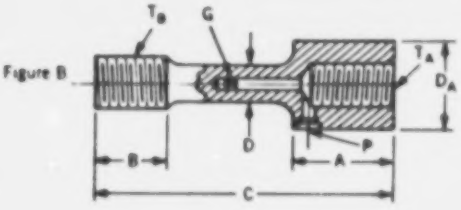


Figure C

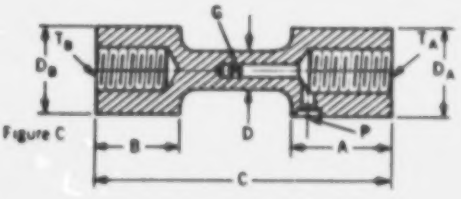


Figure D

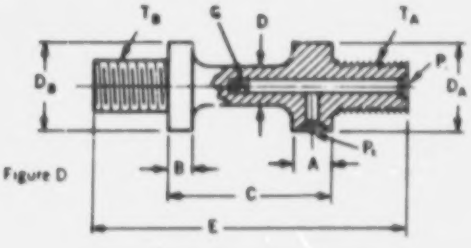
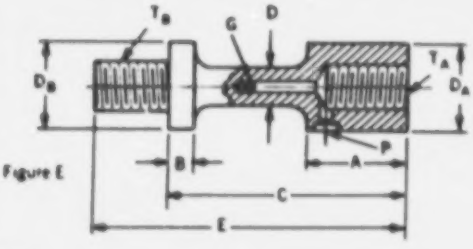


Figure E



LEGEND

P, P_1, P_2 — Provision for lead wires
G — Internal gage installation

T_A, T_B — Threads
D_A, D_B — Diameter for round or across flats for square or hex

READOUT INSTRUMENTS

Any strain indicator on the market can be used with Strainsert Bolts and Studs. Oscilloscopes and recorders suitable for general strain gage work may also be used. We recommend the Strainsert Model HW1-D or TN8C Transducer/Strain Indicator. Both models are the most accurate and versatile strain indicators on the market.

Special simplified instruments for bolt load readout can be furnished on special order. Overload protection systems and special purpose indicating, control and recording equipment for use with Strainsert Bolts and Studs can be designed and manufactured to special order.

CALIBRATION SERVICE AVAILABLE

For applications which require the utmost in accuracy, detailed calibration data can be supplied on order for any Strainsert Bolt and Stud. Loading is done in five equal steps up to maximum load; unloading is done in similar steps in reverse. The entire calibration process is repeated three times. For each step-load, the strain reading or signal is recorded.

Calibration readings are analyzed and compared to either a best fitting or customer specified straight line calibrations. Linearity, repetition, and hysteresis are determined from the data. For calibrations up to 30,000 pounds, a dead-weight loading device is used. Bolts or studs which require higher loads are calibrated on other suitable devices.

ELECTRICAL SPECIFICATIONS

ITEM	CHARACTERISTIC
GAGES	Metal Foil
GAGE FACTOR	2.00
SERVICE TEMPERATURE	150°F or 300°F
LINEARITY	± 1% of Allowable Load
REPETITION	± 0.1%
RESISTANCE	120 ± 2 or 350 ± 5 ohms
CONFIGURATION	Quarter- (QB), Double Quarter- (DQB), or Full-Bridge (FB).
EXCITATION	120-ohm QB: 6V Across Gage
	350-ohm QB: 12V Across Gage
	120-ohm DQB: 6V Across Bridge
	350-ohm DQB: 12V Across Bridge
	120-ohm FB: 6V Across Bridge
	350-ohm FB: 12V Across Bridge

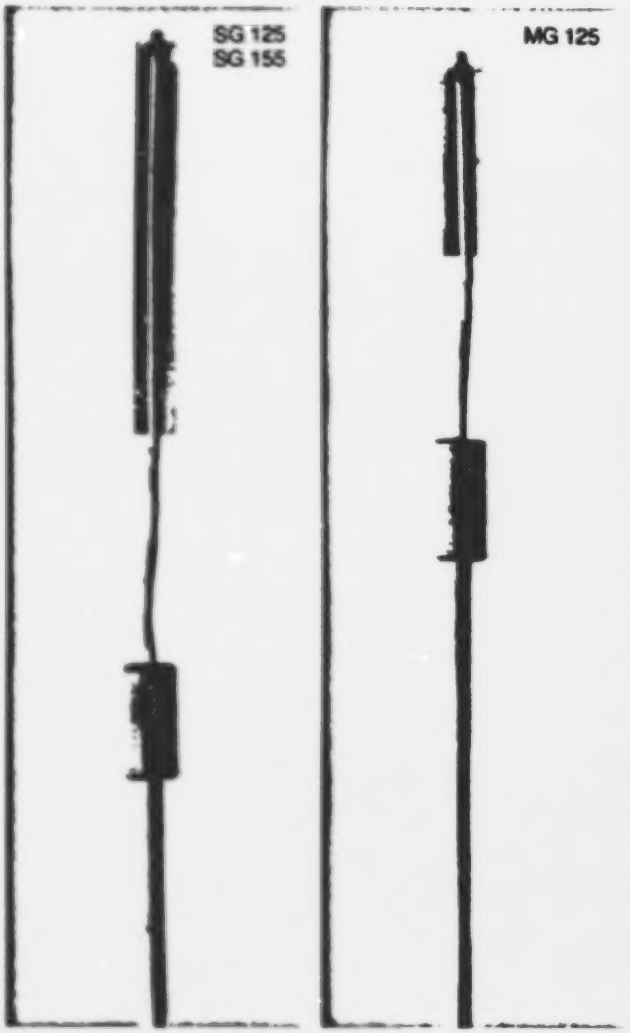
Your Strainsert Representative:

STRAINSERT COMPANY 24 Summit Grove Avenue, Bryn Mawr, Pennsylvania 19010, Telephone (215) 525-0685

E·A·T·N Advanced Electronics

Weldable Strain Gages

SG 125, SG 155, MG 125 Series
120 and 350 OHM Quarter Bridge
For Static Measurement from −452°to 600°F
Dynamic Measurement to 1500°F



FEATURES

- **HIGH TEMPERATURE**
- **600 F STATIC / 1500 F DYNAMIC**
- **SELF TEMPERATURE COMPENSATED**
- **NICKEL-CHROME ALLOY**
- **120 AND 350 OHM RESISTANCE**
- **ALL WELDED CONSTRUCTION**
- **INTEGRAL CABLE**
- **NO ADHESIVES REQUIRED**
- **SIMPLE RAPID INSTALLATION**

DESCRIPTION

AILTECH Sealed Strain Gages are installed quickly in the field, providing immediate, reliable strain data — in almost any environment — at the lowest overall cost by eliminating hours of tedious preparation, installation and gage protection procedures.

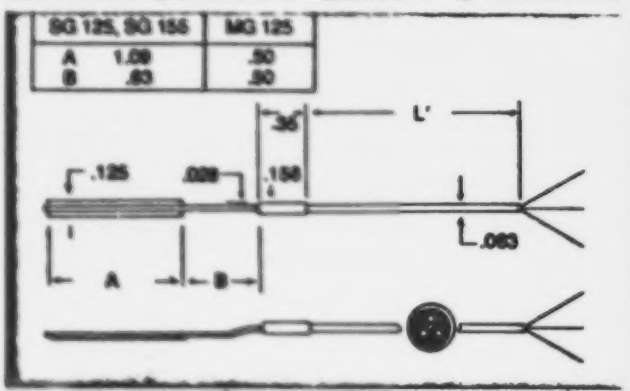
AILTECH Weldable Strain Gages are available with 120 and 350 ohm, quarter bridge, nickel-chrome filaments, and are suitable for static measurements to 600°F, and dynamic measurements to 1500°F. They provide minimum apparent strains and are self-temperature compensated for your material. Quarter bridge gages are normally used from 75° to 600°F for static measurements. Half bridge configurations provide more precise compensation in temperature spans from −452° to +75°F and other cryogenic ranges.

The 350 ohm filament permits higher excitation voltages and reduces errors associated with long leads. All closures on these strain gages are welded. This all-welded construction is the only type gage readily usable in hostile environments such as nuclear reactors, steam turbines, and pressurized chambers.

Every Ailtech Strain Gage is pre-tested at the factory to its maximum operating temperature to assure proper operation in its intended application.

Ailtech Weldable Strain Gages are easily installed using low energy capacitive discharge spot welding equipment. A series of spot welds quickly makes the gage an integral part of the test structure, assuring complete strain transmission.

	SG 125, SG 155	MG 125
A	1.09	.50
B	.83	.90



INTERTECHNOLOGY INC.
3 SCARSDALE ROAD DON MILLS ONTARIO M3B 2R2 (416) 445-5300
MONTREAL OTTAWA WINNIPEG CALGARY VANCOUVER

Eaton Corporation
Electronic Instrumentation Division
5340 ALLA ROAD • LOS ANGELES CA 90066
TELEPHONE (213) 822-3061 • TWX 910-343-6969

SPECIFICATIONS SG 125, MG 125 SG 155 SERIES.

ELECTRICAL SPECIFICATIONS

Strain Gage Resistance:

Model:	SG 125	SG 155	MG 125
Resistance:	120 ohms ± 1*	350 ohms ± 10	120 ohms ± 5

*When compensated for materials with thermal coefficient of expansion between 6.0 and 10.5 ppm/°F. ± 3 ohms when compensated for other expansion ranges.

Integral Lead Wire Resistance:
0.1 ohms / ft at 75°F.

Excitation Current:
Continuous: 50 ma maximum
Pulsed: To 300 ma depending on operating temperature and test structure.

Insulation Resistance:
Greater than 1000 megohms at 50 vdc measured at 75°F.

PERFORMANCE SPECIFICATIONS

Gage Factor:

SG 125 and SG 155	1.9 nominal
MG 125	1.7 nominal

Actual Gage Factor is Reported for Each Lot.
Gage factor for all gages within a particular lot is within ± 3%

Rated Strain Level:
± 20,000 microinches per inch

Fatigue Life:
Exceeds 10^6 cycles at ± 1000 microinches per inch

Transverse Sensitivity:
Negligible (Line weld between strain tube and mounting flange).

ENVIRONMENTAL SPECIFICATIONS

Operable Temperature Range:
static measurements −425 to 600°F.
dynamic measurements −452 to 1500°F.

Compensated Temperature Range 0 to 600°F.:
Gages are individually temperature compensated

Designation	Temperature Range
−11	0 to 180°F
−01	75 to 600°F
−09	Special range

Caution: If the temperature of the strain gage exceeds 850°F, the temperature compensation will be irreversibly affected.

Apparent Strain vs. Temperature

Each gage is treated to produce a zero apparent strain for an installed gage at upper and lower temperature bounds. The standard tolerance for these zero crossings is ± 75 microstrain added to a ± 3% of the unmounted apparent strain at the upper temperature bound.

Gage Factor Change with Temperature:
Gage factor varies inversely with temperature approximately 1% per 100°F over the compensated temperature range.

Additional Environments:
The strain gages have been subjected to the following environments and levels without deterioration of performance.

Linear Sinusoidal Vibration: 35g, 20 to 2000 cps
Static Acceleration: 50 g
Shock: 100 g half sine, 7 millisecond duration
Acoustic Noise: 150 db
Ambient Pressure: Vacuum to 10,000 psi

MECHANICAL SPECIFICATIONS

Strain Gage Configurations:
Reference dimensional outline drawings are shown on front.

Electrical Connections:
Red — Active, Black — Dummy, White — Common

Strain Gage Center:
The strain gage center is at the center of the mounting flange.

Active Gage Length:
0.91" for SG 125, 0.61" for SG 155 and 0.21" for MG 125.

Strain Gage and Mounting Flange Material:
AISI Type 321 stainless steel. Intended for mounting on weldable ferrous and nonferrous materials excluding aluminum and magnesium.

Lead Wire:
Three No. 30 AWG bare copper conductors insulated with compacted magnesium oxide, and encased in AISI Type 347 stainless steel tube.

ORDERING INFORMATION

Detailed ordering information and available options are shown on a separate instruction sheet.

Standard Gages
Standard Gages are stocked in limited quantities for immediate shipment. These gages solve the majority of strain measurement problems encountered. They include ten feet of integral cable, and are compensated to match 1018 steel (6S) or 321 stainless steel (9S) over the temperature range of 75 to 600 Deg. F.

Custom Gages
Ordering of Custom Gages with other cable lengths, other temperature ranges, options, other compensations etc., requires a detailed build-up of the Custom model number.

Consult factory for further information or applications assistance.

Apparent Strain vs. Temperature Curves (Typical) °F

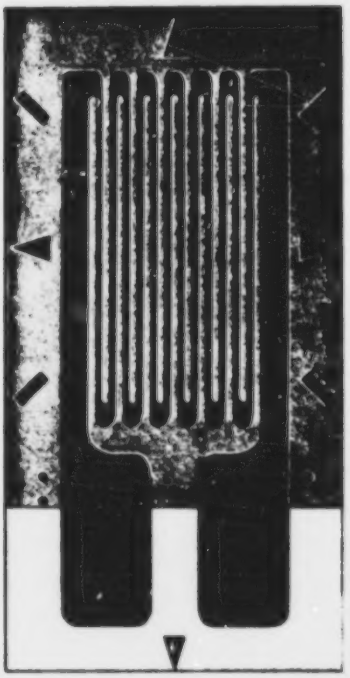
NOTE: FOR TECHNICAL REFERENCE ONLY. FOR UPDATE PRICES AND OTHER CONFIGURATIONS. REFER TO CAT. 200 REV.1.

product bulletin PB-108-2

CEA SERIES STRAIN GAGES

FEATURES

- LARGE INTEGRAL COPPER SOLDER TABS
- ULTRATHIN AND CONFORMABLE
- IMPROVED FATIGUE LIFE
- PRETRIMMED MATRIX
- COMPLETELY ENCAPSULATED GRID



Micro-Measurements CEA SERIES Strain Gages, *the most universal general purpose strain gages yet devised,* feature precision photoformed grids completely encapsulated in polyimide, with integral large, rugged, copper-coated terminals. This construction provides optimum capability for direct leadwire attachment.

Complete elimination of internal jumper wires permits very compact gage/terminal designs. The CEA gage is extremely thin (0.0022 inches/0.056mm) and can be contoured to almost any radius. Improved fatigue life results from removal of all internal discontinuities and can be increased further by using low modulus solders such as M-Line 242-25S or 358-25S.

CEA SERIES gages are pretrimmed to an exact matrix size and squareness. Installation is with any standard strain gage adhesive, and leadwires can be easily soldered directly to the copper terminals. Because of the complete grid encapsulation only a minimum additional protective coating is required for most normal operating environments.

MICRO-MEASUREMENTS
a division of Vishay Intertechnology, Inc.
P. O. Box 306, 38905 Chase Road
Romulus, Michigan 48174

distributed exclusively by
INTERTECHNOLOGY LIMITED
POST OFFICE BOX 219 – DON MILLS, ONTARIO M3C 2S4
Telephone 416–447-9184–447-0738–Telex 06-966772

SPECIFICATIONS

TYPICAL STATIC INSTALLATION No. 26 AWG leadwire connections

TYPICAL DYNAMIC INSTALLATION No. 34 AWG leadwire connections

CONSTRUCTION

Fully encapsulated grid with exposed copper-coated terminals

Foil Alloy: Constantan
Carrier Matrix: Polyimide

Nominal Gage Thickness:
Single Plane: 0.0022 inches (0.056mm)
Stacked Rosettes: 0.0039 inches (0.099mm)

STRAIN LIMITS

±3% to ±5% (dependent upon gage size)

RECOMMENDED ADHESIVES

Compatible with all strain gage adhesives except evaporation-set type

FATIGUE LIFE

SOLDER	STRAIN LEVEL	CYCLES
358-25S	$\pm 1500 \times 10^{-6}$	10^6
361-20R	$\pm 1500 \times 10^{-6}$	10^5

No. 30 AWG (0.25mm diameter) leads directly attached

TEMPERATURE RANGE

NORMAL: -100°F to +400°F (-75°C to +200°C)
Stacked rosettes limited to +125°F (50°C)

SELF-TEMPERATURE COMPENSATION

Test Material	Molyb.	Ti6Al4V	1018 CRS	304 SS	2024-T4 Al.	AZ-31B Mag.
PPM/°F*	2.2	4.9	6.7	9.6	12.9	14.5
PPM/°C*	4.0	8.8	12.1	17.3	23.2	26.1

**Temperature Coefficient of Expansion from +32°F to +212°F (0°C to +100°C).*

GAGE LISTINGS

GAGE PATTERN (Actual Size) Grids are Vertical Except as Noted	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	† Stock Status	RES. IN OHMS	LIST PKG. PRICE (Five Gages)	†DIMENSIONS IN INCHES (mm) ES = Each Section CP = Complete Pattern					
					Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
032UW	CEA-XX-032UW-120	B	120 ±0.3%	24.00	0.032 (0.81)	0.180 (4.57)	0.060 (1.52)	0.120 (3.05)	0.270 (6.9)	0.190 (4.8)
					Notes: General-purpose miniature gage. Exposed solder tab area is 0.07" x 0.04" *(1.8mm x 1.0mm).*					
062UR	CEA-XX-062UR-120	A	120 ±0.4%	77.00	0.062 ES (1.57)	0.220 CP (5.59)	0.062 ES (1.57)	0.420 CP (10.67)	0.320 (8.1)	0.480 (12.2)
	CEA-XX-062UR-350	B	350 ±0.4%	88.00						
					Notes: Small 45° rectangular single-plane rosette in a compact geometry. Exposed solder tab area is 0.07" x 0.04" *(1.8mm x 1.0mm).*					
062UW	CEA-XX-062UW-120	A	120 ±0.3%	19.00	0.062 (1.57)	0.220 (5.59)	0.120 (3.05)	0.120 (3.05)	0.310 (7.9)	0.190 (4.8)
	CEA-XX-062UW-350	B	350 ±0.3%	26.00						
					Notes: General-purpose 1/16" *(1.6mm)* gage. Exposed solder tab area is 0.07" x 0.04" *(1.8mm x 1.0mm).*					

†See Ordering Information on Page 4.

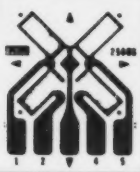
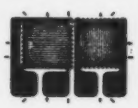
†The dimensions listed for Gage Length, Overall Length, Grid Width, and Overall Width refer to the actual foil pattern, and do not include alignment marks or backing.

GAGE LISTINGS

GAGE PATTERN (Actual Size) Grids are Vertical Except as Noted	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	† Stock Status	RES. IN OHMS	LIST PKG. PRICE (Five Gages)	DIMENSIONS IN INCHES / MILLIMETERS — ES = Each Section, CP = Complete Pattern					
					Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
062WT	CEA-XX-062WT-120	C	120 ±0.5%	50.00	0.062 ES	0.220 CP	0.120 ES	0.220 CP	0.310	0.310
					1.57	*5.59*	*3.05*	*5.59*	*7.9*	*7.9*
	CEA-XX-062WT-350	C	350 ±0.5%	63.00						
					Notes: Small two-element 90° 'tee' stacked rosette. Exposed solder tab area is 0.07" x 0.04" *(1.8mm x 1.0mm).* Maximum operating temperature for stacked rosettes is +125°F *(+50°C).*					
125UR	CEA-XX-125UR-120	A	120 ±0.4%	57.00	0.125 ES	0.300 CP	0.060 ES	0.560 CP	0.420	0.620
					3.18	*7.62*	*1.52*	*14.22*	*10.7*	*15.7*
	CEA-XX-125UR-350	B	350 ±0.4%	68.00						
					Notes: General-purpose 45° single-plane rosette in a compact geometry. Exposed solder tab area is 0.08" x 0.06" *(2.0mm x 1.5mm).*					
125UT	CEA-XX-125UT-120	A	120 ±0.4%	45.00	0.125 ES	0.325 CP	0.165 ES	0.356 CP	0.425	0.455
					3.18	*8.26*	*4.19*	*9.04*	*10.8*	*11.6*
	CEA-XX-125UT-350	A	350 ±0.4%	57.00						
					Notes: General-purpose two-element 90° 'tee' rosette. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					
125UW	CEA-XX-125UW-120	A	120 ±0.3%	18.00	0.125	0.325	0.180	0.180	0.425	0.270
					3.18	*8.26*	*4.57*	*4.57*	*10.8*	*6.9*
	CEA-XX-125UW-350	A	350 ±0.3%	26.00						
					Notes: General-purpose 1/8" *(3.2mm)* gage. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					
125WT	CEA-XX-125WT-120	C	120 ±0.5%	50.00	0.125 ES	0.325 CP	0.180 ES	0.325 CP	0.425	0.425
					3.18	*8.26*	*4.57*	*8.26*	*10.8*	*10.8*
	CEA-XX-125WT-350	C	350 ±0.5%	63.00						
					Notes: Two-element 90° 'tee' stacked rosette. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).* Maximum operating temperature for stacked rosettes is +125°F *(+50°C).*					
187UV	CEA-XX-187UV-120	B	120 ±0.4%	51.00	0.187 ES	0.560 CP	0.150 ES	0.330 CP	0.640	0.390
					4.75	*14.22*	*3.81*	*8.38*	*16.3*	*9.9*
	CEA-XX-187UV-350	B	350 ±0.4%	57.00						
					Notes: Two-element 90° rosette for torque and shear-strain measurement. Sections have a common electrical connection. Exposed solder tab area is 0.13" x 0.08" *(3.3mm x 2.0mm).*					
187UW	CEA-XX-187UW-120	B	120 ±0.3%	17.00	0.187	0.387	0.180	0.180	0.487	0.270
					4.75	*9.83*	*4.57*	*4.57*	*12.4*	*6.9*
	CEA-XX-187UW-350	B	350 ±0.3%	20.00						
					Notes: General-purpose 3/16" *(4.8mm)* gage. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					
250UR	CEA-XX-250UR-120	A	120 ±0.4%	57.00	0.250 ES	0.500 CP	0.120 ES	0.760 CP	0.650	0.800
					6.35	*12.70*	*3.05*	*19.30*	*16.5*	*20.3*
	CEA-XX-250UR-350	B	350 ±0.4%	68.00						
					Notes: Large three-element 45° single-plane rosette. Exposed solder tab area is 0.13" x 0.08" *(3.3mm x 2.0mm).*					

† *See Ordering Information on Page 4.*

GAGE LISTINGS

GAGE PATTERN (Actual Size) Grids are Vertical Except as Noted	GAGE DESIGNATION Insert Desired S-T-C No. in Spaces Marked XX	† Stock Status	RES. IN OHMS	LIST PKG. PRICE (Five Gages)	DIMENSIONS IN INCHES / MILLIMETERS — ES = Each Section, CP = Complete Pattern					
					Gage Length	Overall Length	Grid Width	Overall Width	Matrix Length	Matrix Width
250US 	CEA-XX-250US-120	B	120 ±0.4%	108.00	0.250 ES	0.820 CP	0.120 ES	0.700 CP	0.960	0.800
	CEA-XX-250US-350	B	350 ±0.4%	130.00	*6.35*	*20.83*	*3.05*	*17.78*	*24.4*	*20.3*
					Notes: Four-element full-bridge pattern for shear-strain measurement. Grids are spaced 90° apart, and 45° from pattern centerlines. Exposed solder tab area is 0.16" x 0.10" *(4.1mm x 2.5mm).*					
250UT 	CEA-XX-250UT-120	A	120 ±0.4%	45.00	0.250 ES	0.450 CP	0.290 ES	0.650 CP	0.550	0.740
	CEA-XX-250UT-350	B	350 ±0.4%	57.00	*6.35*	*11.43*	*7.37*	*16.51*	*14.0*	*18.8*
					Notes: General-purpose two-element 90° 'tee' rosette. Exposed solder tab area is 0.13" x 0.10" *(3.3mm x 2.5mm).*					
250UW	CEA-XX-250UW-120	A	120 ±0.3%	17.00	0.250	0.450	0.180	0.180	0.550	0.270
	CEA-XX-250UW-350	A	350 ±0.3%	19.00	*6.35*	*11.43*	*4.57*	*4.57*	*14.0*	*6.9*
					Notes: General-purpose 1/4" *(6.4mm)* gage. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					
375UW	CEA-XX-375UW-120	B	120 ±0.3%	19.00	0.375	0.575	0.180	0.180	0.675	0.270
	CEA-XX-375UW-350	B	350 ±0.3%	23.00	*9.53*	*14.61*	*4.57*	*4.57*	*17.1*	*6.9*
					Notes: General-purpose 3/8" *(9.5mm)* gage. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					
500UW	CEA-XX-500UW-120	A	120 ±0.3%	19.00	0.500	0.700	0.180	0.180	0.800	0.270
	CEA-XX-500UW-350	A	350 ±0.3%	23.00	*12.70*	*17.78*	*4.57*	*4.57*	*20.3*	*6.9*
					Notes: General-purpose 1/2" *(12.7mm)* gage. Exposed solder tab area is 0.10" x 0.07" *(2.5mm x 1.8mm).*					

†*See Ordering Information below.*

ORDERING INFORMATION

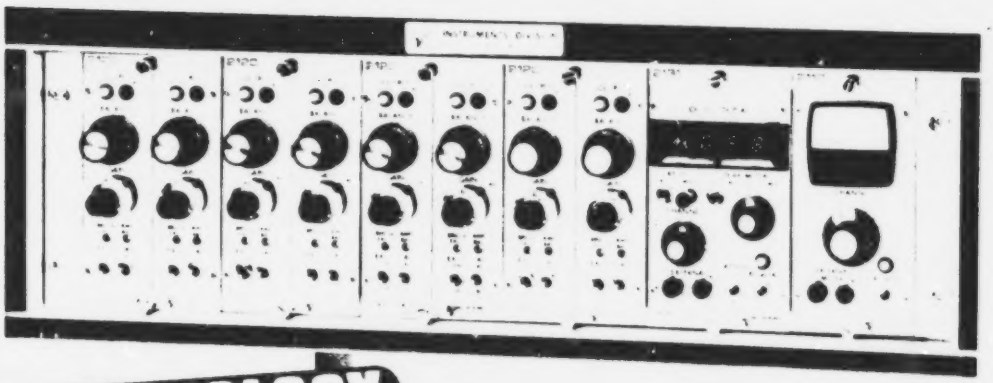
BULLETIN 170-B

STRAIN GAGE INSTRUMENTATION

2100 SYSTEM

MULTICHANNEL SIGNAL CONDITIONER/AMPLIFIER

The 2100 System is used to condition signals from strain gages and transducers when multiple-channel simultaneous dynamic recording is required. A complete ten-channel system is shown.



INTERTECHNOLOGY INC
1 SCARSDALE ROAD, DON MILLS, ONTARIO M3B 2R2 – (416) 445-5500
MONTREAL (514) 683-0930 OTTAWA (613) 563-0522 WINNIPEG (204) 895-2037 CALGARY (403) 256-3088 VANCOUVER (604) 27 -9538

- Accepts Full, Half and Quarter Bridges; All Bridge Completion Resistors Built in Including 120 and 350 Ohm Dummies.
- Fully Adjustable and *Regulated* Bridge Excitation on each Channel; Up to 12 VDC by Front Panel Control.
- Continuously Variable Amplifier Gain up to 2100 by Front Panel Control.
- Output 10 VDC or 100 mA, Short Circuit Proof and Current Limiting Standard.
- Separate Bridge Power Switch.
- LED Null Indicators Provided on each Channel to Indicate Amplifier and Bridge Balance Condition.
- High Stability with Temperature and Time.
- Frequency Response 5 kHz (-0.5 dB, 5%).

INSTRUMENTS DIVISION

MEASUREMENTS GROUP

P.O. Box 27777
Raleigh, NC 27611, USA
(919) 365-3800

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The 2100 System accepts low level signals and conditions and amplifies them into high level outputs suitable for multiple channel simultaneous dynamic recording. Recording devices compatible with the 2100 include galvanometers, strip chart, magnetic tape and X-Y recorders.

The 2100 will accept (without any rewiring) strain gage, load-pressure-transducers and nickel temperature sensor inputs. Thermocouples can also be accommodated.

A 2100 System consists of:

1 to 5 Modules	Model 2120	Strain Gage Conditioner/Amplifier (2 channels/module)
1	Model 2110	Central Power Supply
1	Model 2150	Rack Adapter
	OR	
1 or 2 Modules	Model 2120	Strain Gage Conditioner/Amplifier (2 channels/module)
1	Model 2110	Central Power Supply
1	Model 2160	Portable, 4-Channel Enclosure
	OPTIONAL	
1	Model 2130	LED Readout
	OR	
1	Model 2131	LED Readout

The emphasis in design was to provide a durable system capable of performing equally well in the laboratory and mobile field vans. Another design objective achieved was miniaturization of the system while maintaining adequate spacing around the front panel controls. All operational controls are located on the front panel for maximum set-up efficiency. Frequently used controls are finger-operated, while initial set-up adjustments are made through-the-panel with a screwdriver.

Continuously variable amplifier gain is achieved via a locking ten-turn concentric-dial counting knob, which permits resetting to a predetermined value for repeating routine tests.

A combination of integrated circuits and discrete components was used in the design to assure maximum performance and ease of service at the lowest possible price.

The Model 2130 or 2131 LED Readout expands the capabilities of the 2100 System to include direct channel-by-channel display of data. Peak hold/retention capability is provided with the Model 2131.

MODEL 2120 – STRAIN GAGE CONDITIONER/AMPLIFIER

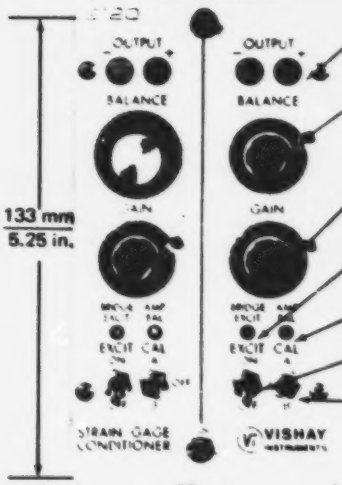
A two channel plug-in module which includes bridge completion, bridge balance, amplifier, amplifier balance, excitation regulator and shunt calibration.

SPECIFICATIONS

These specifications apply for each of two independent channels per module.

INPUTS	Quarter (120Ω and 350Ω), half and full bridge (50-1000Ω). Quarter-bridge dummy resistors provided.
BRIDGE EXCITATION	1 to 12 VDC (adjustable for each channel) with 120Ω full bridge load. Short-circuit current: < 40 mA Ripple, noise, and 10% line change: 2 mV max. Load regulation: ±0.2% no-load to 120Ω load.
BRIDGE BALANCE	±2000 με (quarter, half, or 350Ω full bridge); range can be changed by internal resistor change.
CALIBRATION	Two-position (center off) toggle switch. As delivered: ±1000 με ±1% at G.F. = 2.
AMP GAIN	100 to 2100 continuously adjustable. Gain equal to twice dial reading (±2%)
BANDPASS	DC to 5 kHz (min): -0.5 dB (-5%) DC to 13 kHz: -3 dB
AMP INPUT	Temperature coefficient: ±2 μV RTI/°C (max). Warm-up: 25 μV RTI over 30 minutes. Noise and drift (pk-pk): DC - 10 μV RTI/day; 0.01 to 100 Hz - 3 μV RTI (max); 1 Hz up - 10 μV RTI (max). Input impedance: > 25 MΩ differential or common mode. (Balance limit resistor removed) CMR: DC - 120 dB (min) 0 to 500 Hz - 100 dB. Input bias - ±0.1 μA each unput.

MODEL 2120



LED DISPLAY: set-up/indicator for amplifier balance, bridge balance, tension/compression

BRIDGE BALANCE
Resistively balancing the bridge
Standard locking knob
Digital locking knob ("K" option)

GAIN: varies amplifier gain between 100-2100

BRIDGE EXCITATION: varies bridge excitation between 1-12 VDC

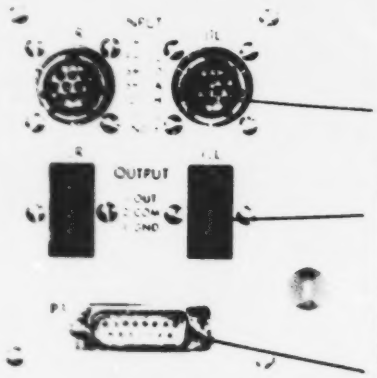
AMPLIFIER BALANCE: adjusts amplifier offset

BRIDGE EXCITATION: (on-off) removes bridge excitation

SHUNT CALIBRATION: (2 points)

INPUT TRANSISTOR PAIR WITH SPECIAL HOUSING

SPECIAL PORTION OF PRINTED CIRCUIT BOARD FOR SHUNT CALIBRATION RESISTORS AND JUMPERS



REAR

OUTPUT	±10 V (min) at 30 mA. ±50 mA (min) into 150Ω load. ±100 mA (min) into 15Ω load. Current limit: 120 mA. Linearity: ±0.05% at DC.
SIZE & WEIGHT	5.25 in H x 2.94 in W x 10.97 in D (133 mm x 75 mm x 279 mm) 2.3 lb (1.0 kg)

All specifications nominal or typical at 23°C unless noted.

MODEL 2110 – CENTRAL POWER SUPPLY

A plug-in module capable of powering up to ten channels (5 Model 2120 Modules) at maximum rated voltage or current. Provides initial bridge and amplifier voltages. All supplies are current limited against amplifier malfunction.

SPECIFICATIONS

OUTPUTS	±15V at 1.2A and + 17.5 V at 1.1 A; all regulators current-limited against overload.
INPUT	107, 115, 214, 230 VAC ±10% 50/60 Hz (selected internally). Power: 40 W typical, 100 W max.
METER	0 to 12 VDC (with switch) to read bridge excitation. Also AC input and DC output go/no-go monitor.
SIZE & WEIGHT	5.25 in H x 2.44 in W x 12.34 in D (133 mm x 62 mm x 313 mm) 6.5 lb (2.9 kg)

MODEL 2130/2131 – DIGITAL DISPLAY

See Bulletin 171 for complete description and specifications.

MODEL 2150 – RACK ADAPTER

A 19 inch (483 mm) prewired rack adapter which accepts one Model 2110 and up to five Model 2120 plug-in modules. It has its own fuse and power cord and can be housed in any standard electronic enclosure.

SPECIFICATIONS

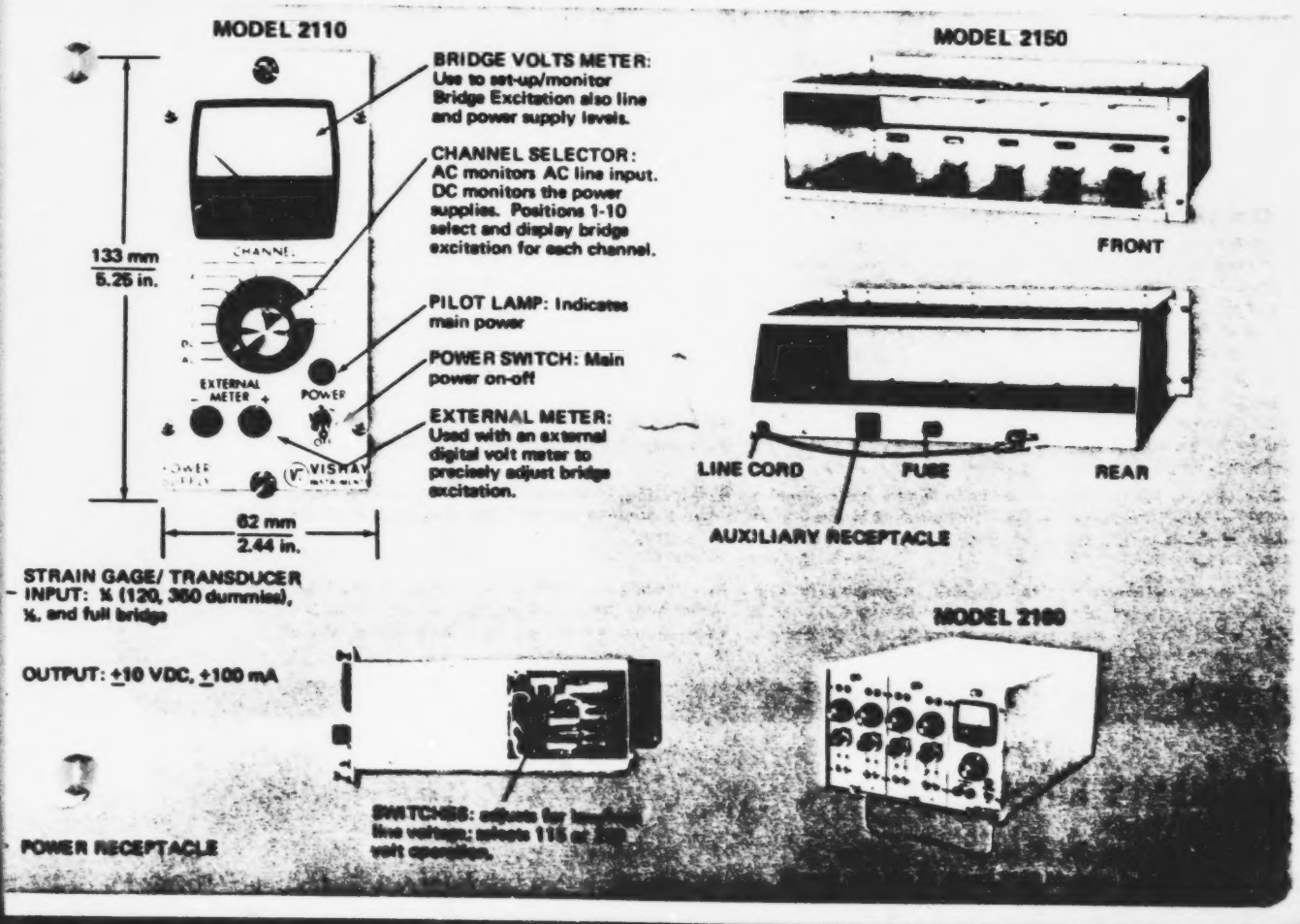
APPLICATION	Fits standard 19-in (483 mm) electronic equipment rack. Accepts one 2110 Power Supply and one to five 2120 Strain Gage Conditioners. Completely wired.
POWER	2 ft (0.6 m) 3-wire line cord; 10 ft (3 m) extension available. Fuse: 1 A size 3 AG (32 mm x 6.4 mm dia). Receptacle to accept line cord from adjacent 2150 Rack Adapter.
SIZE & WEIGHT	5.25 in H x 19 in W x 12.82 in D overall. (133 mm x 483 mm x 325 mm) 7.0 lb (3.2 kg)

MODEL 2160 – PORTABLE 4 CHANNEL ENCLOSURE

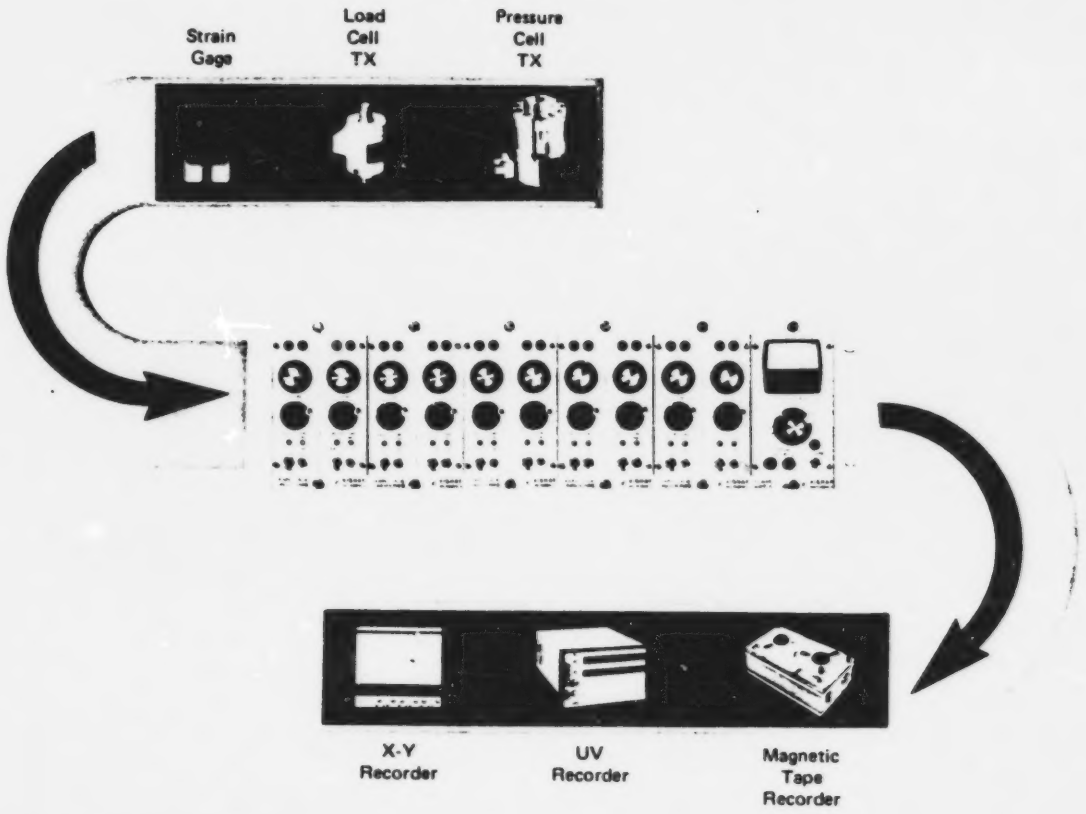
A prewired, fused enclosure which houses one 2110 Power Supply and one or two 2120 Strain Gage Conditioner/Amplifier Modules. A carrying handle (not visible in the photograph) ensures maximum portability. An additional snap-down bail handle on the bottom of the Model 2160 can be used to elevate the instrument for excellent work efficiency during bench-top operation. The Model 2160 would be substituted for the Model 2150 when 2 or 4 channels and maximum portability is required.

SPECIFICATIONS

SIZE & WEIGHT	8.75 in W x 5.5 in H x 13.13 in D (222W x 140 H x 333D mm) 5.5 lb (2.5kg)


MODEL 2110
BRIDGE VOLTS METER: Use to set-up/monitor Bridge Excitation also line and power supply levels.
CHANNEL SELECTOR: AC monitors AC line input. DC monitors the power supplies. Positions 1-10 select and display bridge excitation for each channel.
PILOT LAMP: Indicates main power
POWER SWITCH: Main power on-off
EXTERNAL METER: Used with an external digital volt meter to precisely adjust bridge excitation.
133 mm 5.25 in.
62 mm 2.44 in.
CHANNEL
EXTERNAL METER
POWER
VISHAY
STRAIN GAGE/ TRANSDUCER INPUT: ¼ (120, 360 dummies), ½, and full bridge
OUTPUT: ±10 VDC, ±100 mA
POWER RECEPTACLE
SWITCHES: adjusts for
line voltage; selects 115
volt operation.
MODEL 2150
FRONT
LINE CORD
FUSE
REAR
AUXILIARY RECEPTACLE
MODEL 2160

2100 SYSTEM WITH I/O DEVICES



The 2100 System provides better data:

By a separate bridge power switch which enables the operator to remove bridge excitation. This permits detection of unwanted signals due to electrical interference and/or noise, thermocouple effects and shifts of the instrument zero during a long-term test. Not found on other signal conditioners, but an absolute must for dynamic testing, and for validating test results.

By an adjustable bridge excitation control on each channel. This permits setting the recommended excitation as specified by the strain gage or transducer manufacturer. It also allows for any special consideration which may be dictated by the test material; for example, poor thermal conductivity normally associated with plastics.

By each channel having its own regulator circuit and not just a rheostat for adjusting bridge voltage. This prevents interaction of adjacent channels during set-up or operation, which is somewhat typical of other inexpensive systems.

By a continuous variable gain on each channel. In combination with recommended excitation, the independent gain control can provide a large output signal so that small signals can be resolved without overpowering the strain gage or transducer.

By using a LED display on each channel as a positive indication of amplifier and resistive balance. This accelerates set-up time, minimizes the risk of destroying galvanometers and verifies tension/compression loading.

By providing bands on the set-up meter to indicate acceptable line voltage and proper operation of internal power supplies.

By a switch contained in the 2110 power supply which allows the line voltage to be adjusted when it is too high or too low.

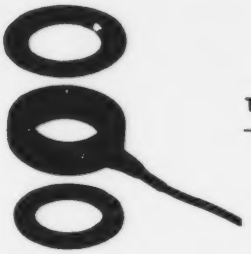
By providing true quarter bridge, 3 lead wire capability, including internal dummies and sufficient plug connections for remote shunt calibration.

By providing a convenient network in the 2120 Strain Gage Conditioner/Amplifier so that you may change the factory supplied shunt values as well as shunt any leg of the bridge as required.

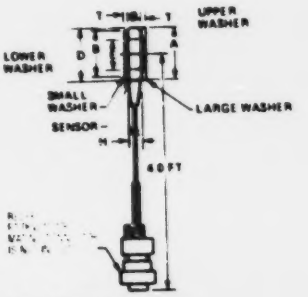
MEASUREMENTS GROUP, INC.
INSTRUMENTS DIVISION
P.O. Box 27777, Raleigh, NC 27611, USA
(919) 365-3800 • TWX 510-920-0770 • Telex 802-502

941113TD
Printed in USA

BOLT FORCE SENSOR



To order, specify model number and load capacity —see chart opposite page



WHEN NUT IS TURNED

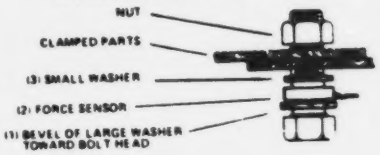
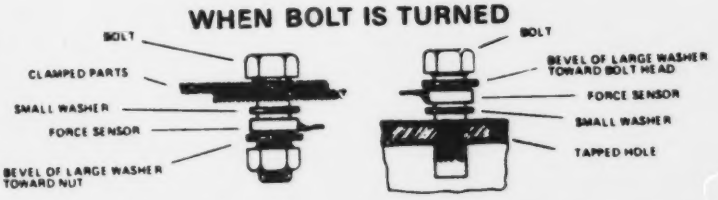


Figure 1

WHEN BOLT IS TURNED



The Bolt Force Sensor is another unique transducer from Lebow® which is essentially a hollow-compression strain gage load cell. It is designed to be used with any strain gage indicator, but when coupled to the Lebow® Model 7530 Indicator, the readout is in true pounds of compression force. Controls, available on the 7530 Indicator, allow the user to reset zero and span for observation of long term changes in tension sensed by the Bolt Force Transducer that is left assembled in a joint.

The Bolt Force Sensor is a three piece assembly consisting of:

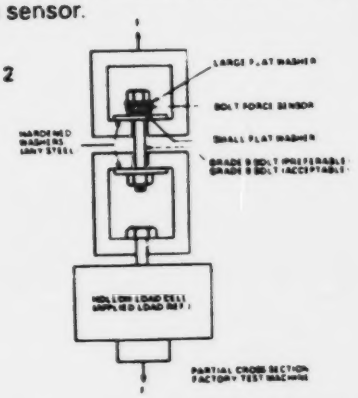
1. A large hardened and ground flat washer with one side beveled.
2. The sensor.
3. A small hardened and ground washer.

NOTE: The use of both washers is mandatory. The three pieces are assembled for various applications as illustrated in figure 1. The large washer isolates the sensor from the force application tool. The beveled hole in this washer, which always faces away from the sensor, provides clearance for the bolt head radius. When a torque wrench is used, a torque vs. clamp force curve can be generated.

The 3711 Bolt Force Sensors is designed for use in fastener testing where the compression loading of the sensor is induced by the tensile loading of the fastener. The bolt force sensor must be used with the size fastener for which it was designed.

The flat washers must be used to prevent damage to the sensor. If washers are substituted for those supplied with the sensor, it is imperative that the factory be consulted prior to implementation. Stress applied to the integral cable assembly will result in sensor damage. The installations illustrated are the recommended applications; other methods may result in reduced performance or damage to the sensor.

Figure 2



To implement correlation between calibration data supplied and the data obtained by the users, a calibration set-up is described which illustrates a recommended testing method. Figure 2 partially illustrates a compression-tension testing machine set-up which applies a compressive load to the bolt sensor. Note that the machine applies a tensile load to a test bolt and the inclusion of the factory-supplied large and small flat washers. The applied load is measured accurately by means of a hollow load cell which is loaded in compression.

Specifications	3711
Sensor	4 arm strain gage bridge
Bridge resistance: ohms nominal	120
Bridge voltage	6 volts maximum
Output at rated capacity	2 to 5 mv/v nominal depending on size
Temperature range, compensated: °F	+70 to +170
Temperature range, useable: °F	−65 to +200
Effect of temperature on zero	±0.01% of full scale per °F.
Effect of temperature on output	±0.02% of reading per °F.

FEATURES

- compact
- high output
- standard models for bolts size no. 6 through 2" and up to 20MM
- sensor and washers—carpenter 440C stainless steel, hardness R_C 58-60
- sensitive to neither bolt or nut applied torque

A pure compressive load applied equally across the large washer area will result in a different distribution of sensor internal stress, deflection, and output signal. This is illustrated in figure 3. Note particularly that a high degree of flatness and parallelism of the machine load faces does not improve the validity of the method. A similar conclusion is arrived at in the case of the application of uniform load across the area of the bolt head; the bolt head deflection is restrained and the sensor output may not correlate satisfactorily.

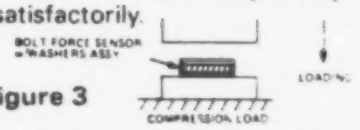


Figure 3

Although not recommended, it is possible to use a smaller size bolt than specified for a given sensor if the application permits an increase in height. Figure 4 illustrates an adapter which can be used to accommodate a smaller size bolt. It is important to note that the deflection of the adapter must be approximately equal to that obtained with the specified size bolt for the sensor. This is the limiting factor in terms of performance of the sensor. For example, for a 3711-750 (¾"), the adapter deflection should be approximately equal to that of a ¾" bolt head.

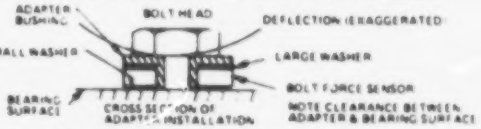


Figure 4

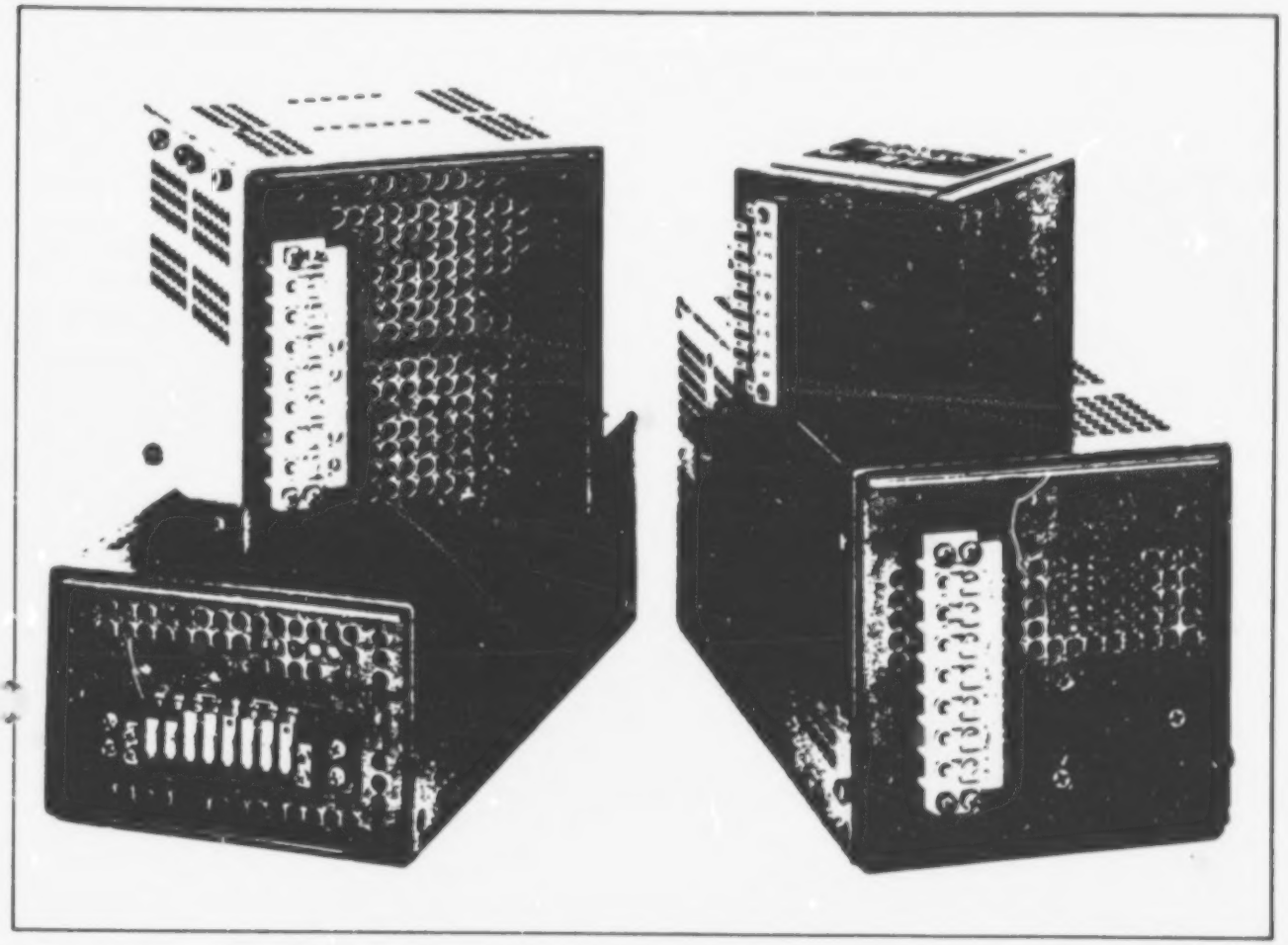
Non-linearity and hysteresis specifications are not the same for all sizes of bolt force sensors. Each particular size has a characteristic curve which is not necessarily the same as for other sizes. Typically, non-linearity and hysteresis may be 4% of full scale. A similar statement applies to the full-range output as well. Consult the factory for information on high capacity (Model 3714) or high temperature (Model 3718) models.

Model No	Bolt Size	Capacity	Deflection	Bolt Force Sensor			Large & Small Washers		
				H	D	E	A	B	T
	in	Lbs	in	in	in	in	in	in	in
	cm	N	cm	cm	cm	cm	cm	cm	cm
3711-138	No 6	1 200	0012	150	437	140	437	281	040
-164	No 8	1 800	0012	150	437	166	437	281	040
-190	No 10	2 400	0012	150	500	192	500	344	040
3711-250	¼	4 000	0014	150	625	262	625	500	062
-312	5/16	7 000	0014	150	750	326	750	562	062
-375	⅜	10 000	0016	187	750	396	750	656	062
-437	7/16	14 000	0016	187	875	454	875	718	062
-500	½	20 000	0020	250	1 000	517	1 000	844	078
-562	9/16	25 000	0020	250	1 125	580	1 125	968	078
-625	5/8	30 000	0020	250	1 125	644	1 125	1 031	078
-750	¾	45 000	0028	375	1 500	770	1 500	1 218	093
-875	⅞	60 000	0028	375	1 500	897	1 500	1 422	093
-1000	1	80 000	0034	500	1 750	1 024	1 750	1 609	093
-1125	1⅛	80 000	0034	500	2 000	1 150	2 000	1 812	093
-1250	1¼	125 000	0053	625	2 250	1 279	2 250	2 125	125
-1500	1½	190 000	0081	875	2 625	1 533	2 625	2 500	125
-1750	1¾	260 000	0111	1 125	3 000	1 787	3 000	2 875	125
-2000	2	300 000	0128	1 375	3 125	2 041	3 125	2 875	125
3711-6MM	6MM	16 000	0014	150	625	238	625	437	062
				381	1 58	604	1 58	1 11	157
-7MM	7MM	27 000	0014	150	625	278	625	484	062
				381	1 58	706	1 58	1 23	157
-8MM	8MM	31 000	0014	150	750	326	750	562	062
				381	1 91	828	1 91	1 43	157
-9MM	9MM	36 000	0014	150	750	356	750	594	062
				381	1 91	904	1 91	1 51	157
-10MM	10MM	46 000	0016	187	750	396	750	656	062
				475	1 91	1 01	1 91	1 66	157
-12MM	12MM	67 000	0016	187	1 000	474	1 000	812	062
				475	2 54	1 20	2 54	2 06	157
-14MM	14MM	102 000	0020	250	1 125	553	1 125	937	078
				635	2 85	1 40	2 85	2 38	198
-16MM	16MM	135 000	0020	250	1 125	644	1 125	1 031	078
				635	2 85	1 64	2 85	2 62	198
-18MM	18MM	156 000	0027	375	1 250	711	1 250	1 187	078
				952	3 17	1 81	3 17	3 01	198
-20MM	20MM	230 000	0034	375	1 500	790	1 500	1 250	093
				952	3 81	2 00	3 81	3 17	236

* SAFETY CONSIDERATIONS "It would be unsafe to operate Labow® Torque Sensors and Load Cells beyond Static Overload or Ultimate Extraneous Load Limits as defined on page 111 in the Glossary of Terms or, when applicable, higher than maximum speed. When in doubt consult the factory. Eaton Corporation is not responsible for any property damage or personal injury which may result because of the misapplication of the Transducer."

5 YEAR GUARANTEED LINEAR

Lambda LC series



Features — LC series

9 package sizes

0.01% Reg line or load

250 μV RMS Ripple

5-year guaranteed

Computer grade hermetically sealed 10-year life electrolytic capacitors.

Lambda MIL-T-27C grade 6 magnetics layer wound with electrostatic shield

Integrated circuit that replaces up to 32 discrete components for higher reliability

Lambda CC4®* Printed Circuit Board plated thru-holes fungus inert, flame retardant
***Licensee of Photo Circuits Inc.**

Designed for use with breadboard, in laboratory or where precision is needed.

Meets military environmental specifications MIL-STD-810B, MIL-E-5272C, MIL-I-6181D

MIL-R-26 type wire wound resistors

Rugged convection-cooled chassis

MIL-W-16878 Wire UL approved

MIL-R-22684 type film resistors

MIL-R-11 composition resistors

UL — Recognized

Specifications—LC Series

DC Output
Voltage range shown in tables

REGULATED VOLTAGE

regulation, line	0.01% + 1 mV
regulation, load	0.01% + 1 mV
ripple and noise	250 μV RMS, 1 mV pk-pk
remote programming resistance	1000 ohms/volt, nominal
remote programming voltage	volt per volt
temperature coefficient	(0.01% + 300 μV)/° C with external programming resistor; (0.015% + 300 μV/° C with internal programming resistor)

AC Input

line	105-132 VAC; 47-440 Hz. Derate 10% for 50 Hz operation. For operation at other than 57-63 Hz and 187-242 VAC, see AC input option. For 360-440 Hz ratings consult factory.
power	LCS-2, LCD-2 20 watts. LCS-A 80 watts. LCD-A 55 watts. LCD-4 125 watts. LCS-B 125 watts. LCS-C 215 watts. LCS-CC 300 watts. LCD-D 460 watts. LCS-E 700 watts. LCS-EE 850 watts.

Ambient Operating Temperature Range
Continuous duty from —20° C to +71° C with corresponding load current ratings for all modes of operation.

Storage Temperature Range
—55° C to +85° C

Overload Protection

THERMAL
Thermostat, automatic reset when over-temperature condition is eliminated. (Not applicable to LCS-2, LCD-2, LCS-A, and LCD-A models.)

ELECTRICAL
External overload protection, automatic electronic current limiting circuit limits the output current to a preset value thereby providing protection for the load as well as the power supply.

Overshoot
No overshoot on turn-on, turn-off or power failure.

Input and Output Connections
Through terminal block on chassis.

Integrated Circuit Regulation
Integrated circuit provides regulation system, except for input and output capacitors, rectifiers and series regulation transistors.

Convection Cooled
No external heat sinking or forced air required.

Number of Package Sizes
Nine (9). Package 2, A, B, 4, C, CC, D, E, EE.

Controls

DC Output Control
Simple screwdriver voltage adjustment over entire voltage range.

Remote Sensing
Provision is made for remote sensing to eliminate effect of power output lead resistance on DC regulation. A terminal (RP) is provided for remote programming which eliminates interaction with internal voltage control, on LCS-CC, LCS-D, LCS-E, and LCS-EE models.

Current Limit
140% of 40° C rating for LCS-2, LCD-2, LCS-A, LCD-A. 130% of 40° C rating for LCD-4, LCS-B, LCS-C, LCS-CC, LCS-D, LCS-E, LCS-EE.

Mounting
LCS-2, LCD-2 four mounting surfaces. LCS-A, LCD-A, LCD-4, LCS-B, LCS-C, LCS-CC, and LCS-D three mounting surfaces designed to mount in Lambda standard rack adapters. LCS-E and LCS-EE one mounting surface in horizontal plane.

Mil Spec
Altitude: MIL-STD-810 Meth. 500.1, Procedure I, high temperature MIL-STD-810B, Meth. 501.1, Procedures I & II, MIL-E-5272C, Para 4.1.2, Procedure II, low temperature. MIL-STD-810B, Method 502.1, Procedure I, temp. shock: MIL-STD-810B, Meth. 503.1, Procedure I, MIL-E-5272C, Para. 4.3.1, Procedure I, Humidity: MIL-STD-810B, Meth. 507.1, Procedure I, MIL-E-5272C, Para. 4.4.1, Procedure I, shock: MIL-STD-810B, Meth. 516.1, Procedures I, III, MIL-E-5272C, Para. 4.15.5.1, 4.15.5.2, vibration: MIL-STD-810B, Notice 1, Meth. 514, Procedures X, XI, emi: MIL-I-6181D.

Physical Data

Package Model	Weight Lbs. Net	Weight Lbs. Ship	Size Inches
LC-2	2-1/4	3-1/8	3-5/32 x 3-9/32 x 3-9/32
LC-A	6	7	3-3/16 x 3-3/4 x 6-1/2
LC-4	8	9	4-29/32 x 4-29/32 x 5
LC-B	7	8	3-3/16 x 4-15/16 x 6-1/2
LC-C	10	11	3-3/16 x 4-15/16 x 9-3/8
LC-CC	15	17	4-15/16 x 4-15/16 x 9-3/8
LC-D	23	26	4-15/16 x 7-1/2 x 9-3/8
LC-E	27	29	4-15/16 x 7-1/2 x 11-3/4
LC-EE	37	47	4-15/16 x 7-1/2 x 16-1/2

Finish
Gray FED. STD. 595 No. 26081.

Accessories
Rack adapters, overvoltage protectors, chassis slides and blank panels. See pages 66-68.

Options

AC Input

Add Suffix	For Operation at:	Price Qty. 1-14	Price Single Model Qty. 15 & Up	Price Mixed Models Qty. 15 & Up
—V	187-242 VAC 47-440 Hz	12% or $45*	10%	12% or $45*
—V1	205-265 VAC 47-440 Hz	12% or $45*	10%	12% or $45*

*Whichever is greater

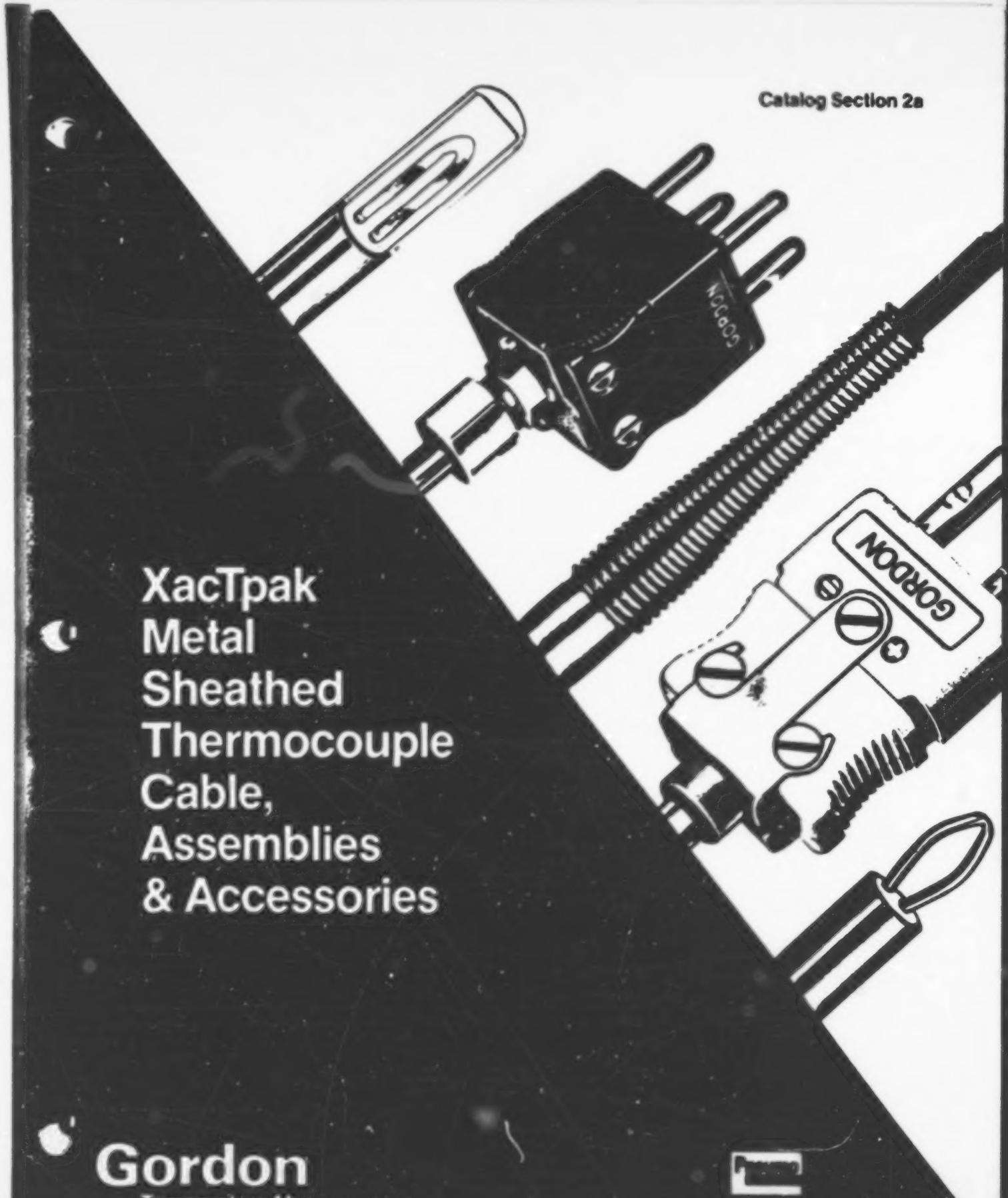
Derate current 10% for 47-53 Hz operation.

Fungus Proofing
Add suffix -"R"- all models can be obtained with MIL-V-173 varnish to render all fungi nutrient components inert. LC series single output models add $15.00 to price, LC series dual output models add $22.50 to price.

Guaranteed for 5 Years
5-year guarantee includes labor as well as parts. Guarantee applied to operation at full published specifications at end of 5 years.

RU — Recognized

Catalog Section 2a



XacTpak Metal Sheathed Thermocouple Cable, Assemblies & Accessories

Gordon
Temperature Measurement

In This Bulletin

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Care, Handling & Fabrication of XacTpak Material	15
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XacTpak® Quality Metal Sheathed Cable

XacTpak is Claud S. Gordon Company's trade name for the metal sheathed, mineral-insulated thermocouple cable it helped pioneer. The unique properties of XacTpak type material make it ideally suited for a wide variety of problem applications.

Important Features of XacTpak: Moistureproof • Pressure Resistant • Thermal Shock Resistant • High Temperature Rated • Fast Responding • Accurate • Formable • Weldable • Durable • Compact.

Typical Applications: Heat Treating • Furnaces • Kilns • Turbines • Bearing Temperature • Power Stations • Steam Generators • Diesel Engines • Nuclear Reactors • Atomic Research • Jet Engines and Test Cells • Rocket Engines • Blast Furnaces • Glass Melting • Refineries • Oil Processing • Catalytic Reformers.

Quality Control & Testing: To maintain quality and consistency, XacTpak is manufactured under carefully controlled procedures and rigid standards of cleanliness. Quality checks are made at critical points throughout the manufacturing process.

Although the raw tubing used in the manufacture of XacTpak is received "thermocouple clean," it is recleaned just prior to assembly. To prevent moisture absorption, the insulators are stored in ovens and loaded while still hot. The loading operation is performed in a climate controlled "clean room." Surgical gloves are used to protect the scrupulously prepared tubing, wire and insulators. Immediately after loading, the subassemblies are compacted and sealed to prevent contamination.

All XacTpak is inspected and tested for conductor uniformity, electrical continuity, insulation resistance, calibration conformance and physical dimensions. Special testing and certification, including helium leak, X-ray, dye penetrant and time response among others, is available on request. For a more complete discussion of Gordon's advanced technological capabilities, refer to Catalog Section 5a.

Sheath Materials: Virtually any malleable metal can be used as XacTpak sheath material. Some of the more commonly used materials and their maximum continuous operating temperatures in an oxidizing atmosphere are:

Inconel 600*	+2100° F (1149° C)
Inconel 601*	+2100° F (1149° C)
Inconel 702*	+2200° F (1204° C)
304 Stainless Steel	+1650° F (899° C)
310 Stainless Steel	+2100° F (1149° C)
316 Stainless Steel	+1700° F (927° C)
347 Stainless Steel	+1600° F (871° C)
446 Stainless Steel	+2000° F (1093° C)

*Trade names of the International Nickel Co., Inc. Where temperature permits, Inconel 600 may be used in vacuum applications. Inconel 702 is not recommended for vacuum use.

Unless otherwise specified, XacTpak is annealed in a protective atmosphere. No oxide removal is necessary prior to welding.

For temperatures exceeding 2200° F (1204° C), noble or refractory metals are used for sheathing. These types of materials are covered in our Catalog Section 5a.

Conductor Materials: The thermocouple material used in XacTpak meets or surpasses all applicable ANSI standards. Bulk XacTpak covering every ANSI recognized thermocouple calibration type is kept in stock at our Richmond, Illinois plant. Gordon will also manufacture XacTpak type material incorporating other conductor materials of your choice; copper and stainless steel are commonly specified alternatives.

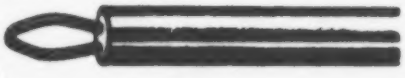
Insulation: The insulation used in XacTpak is extremely high purity (99.4% or better) metallic oxide. During the manufacturing process, the insulation is highly compacted, which excludes air from the sheath, retards moisture absorption and prevents "powdering out". The high degree of compaction achieved also ensures high thermal conductivity and maximum dielectric strength.

Magnesium Oxide (MgO) insulation is standard unless otherwise specified. Other insulating materials supplied on special order include Aluminum Oxide (Al_2O_3), and Beryllium Oxide (BeO).

Gordon offers many highly specialized designs not shown in this catalog. If you do not find exactly what you are looking for, please contact your Gordon representative for assistance.

Hot or Measuring Junctions Available in single or dual[1] element wire

E



Exposed Junction (E)

Thermocouple wires are butt welded. Insulation is sealed against liquid or gas penetration. This junction style provides the fastest possible response time but leaves the thermocouple wires unprotected against corrosive or mechanical damage.

G

Grounded Junction (G)

The sheath and conductors are welded together forming a completely sealed integral junction. Recommended in presence of liquids, moisture, gas or high pressure. The wire is protected from corrosive or erosive conditions.

U

Ungrounded Junction (U)

Thermocouple junction is fully insulated from welded sheath end. Excellent for applications where stray emf's would affect the reading and for frequent or rapid temperature cycling.

[1]When ordering dual element ungrounded or exposed junction styles, specify "common" (four wires junctioned together) or "separate" (each element junctioned independently).

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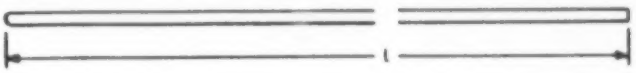
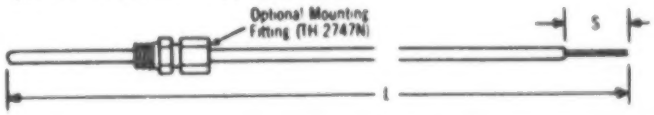
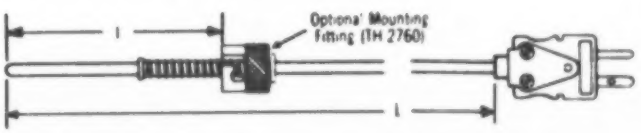
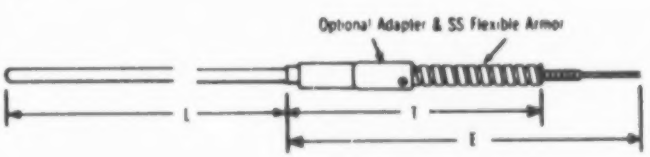
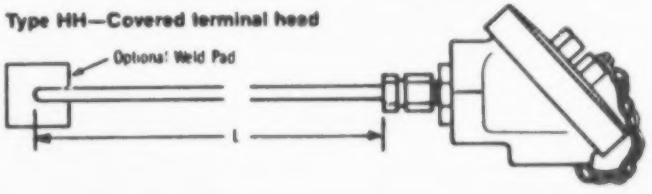
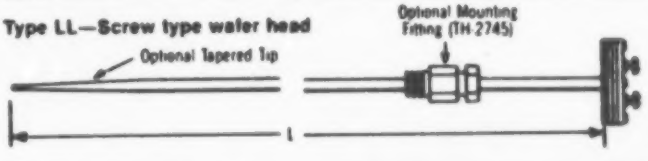
Made-to-Order XacTpak® Thermocouple Assemblies

To specify a Made-To-Order XacTpak thermocouple assembly, select the basic assembly type from the following illustrations and complete the easy step-by-step ordering instructions

Assembly Style	To Order, Specify	Refer to Page Number	Sample Ordering Information
Type AA—Cold end squared & sealed	1 Assembly Type AA	—	1 AA
	2 Element Catalog Number & L Dimension	6	2 401-2107 L = 12"
	3 Measuring Junction Style	2	3 G
	List any desired optional features		
	Mounting Fitting(s)	7 & 8	
	Weld Pad	5	
	Tapered Tip	5	
Type BB—Cold end stripped & sealed	1 Assembly Type BB	—	1 BB
	2 Element Catalog Number & L Dimension	6	2 404-1104 L = 23"
	3 Measuring Junction Style	2	3 U
	4 S Strip Length	—	4 S = 1"
	List any desired optional features		5 TH-2747N-063
	Mounting Fitting(s)	7 & 8	
	Weld Pad	5	
	Tapered Tip	5	
Type DD—Plug or Jack mounted on cold end	1 Assembly Type DD	—	1 DD
	2 Element Catalog Number & L Dimension	6	2 402-1107 L = 15"
	3 Measuring Junction Style	2	3 G
	4 Adapter for Mounting Plug or Jack	12	4 932-125
	5 Plug or Jack	12	5 900J
	List any desired optional features		6 TH-2760 T = 12"
	Mating Plug or Jack	12	
	Mounting Fitting(s)	7 & 8	
	Weld Pad	5	
	Tapered Tip	5	
Type FF—Transition fitting & lead wire	1 Assembly Type FF	—	1 FF
	2 Element Catalog Number & L Dimension	6	2 402-4111 L = 10 ft
	3 Measuring Junction Style	2	3 G
	4 Transition Fitting (add required temperature rating if higher than 300°F/149°C)	11	4 701-250 (750°F) 5 E20-3-201 E = 15 ft 6 TH-195 T = 14 ft 6 in
	5 Lead Wire & E Dimension	11	7 TH-213
	List any desired optional features		
	Mounting Fitting(s)	7 & 8	
	Armor over lead wire (specify T length of armor)	11	
	Plug or Jack	12	
	Spade Lugs	Not Listed	Specify Type & Size
	BX Connector	Not Listed	Specify Type & Size
	Weld Pad	5	
	Tapered Tip	5	
Type HH—Covered terminal head	1 Assembly Type HH	—	1 HH
	2 Element Catalog Number & L Dimension	6	2 402-1111-050 L = 24"
	3 Measuring Junction Style	2	3 U Separate
	4 Head Mounting Fitting	7 & 8	4 TH-185-5
	5 Head	9 & 10	5 TH-2706D
	List any desired optional features		6 1 x 1 x ⅛ 304SS Series 2 Weld Pad
	Mounting Fitting(s)	7 & 8	
	Weld Pad	5	
	Tapered Tip	5	
Type LL—Screw type water head	1 Assembly Type LL	—	1 LL
	2 Element Catalog Number & L Dimension	6	2 402-1107 L = 12"
	3 Measuring Junction Type	2	3 G
	4 Water Head	9 & 10	4 TH-2757-125
	List any desired optional features		5 TH-2745-125
	Mounting Fitting(s)	7 & 8	6 Pencil Taper to .063" O.D.
	Weld Pad	5	
	Tapered Tip	5	

Bulk XacTpak® with MgO Insulation

The following bulk XacTpak items are generally kept in stock at our Richmond, Illinois plant for immediate delivery. In addition to these standard items, Gordon will also manufacture "special" metal sheathed, mineral insulated cable to meet many specialized requirements. Constructions utilizing virtually any malleable metal sheath or conductor materials and any of several insulation types are possible. Consult your Gordon representative for further information.

Single Element

Sheath O.D.	Catalog Number	Sheath Material	ANSI Calibration	Nominal B. & S. Gauge
.010" +.001", -.0005"	402-1116	304 SS	J	44
	402-2116	304 SS	K	44
.020" +.001", -.0005"	401-2101	Inconel 600	K	38
	402-1101	304 SS	J	38
	402-2101	304 SS	K	38
	402-3101	304 SS	T	38
	404-2101	316 SS	K	38
.032" +.001", -.0005"	401-2102	Inconel 600	K	34
	402-1102	304 SS	J	34
	402-2102	304 SS	K	34
	402-3102	304 SS	T	34
.040" +.001", -.0005"	401-1103	Inconel 600	J	32
	401-2103	Inconel 600	K	32
	402-1103	304 SS	J	32
	402-2103	304 SS	K	32
	402-3103	304 SS	T	32
	402-4103	304 SS	E	32
	404-2103	316 SS	K	32
.063" ±.001"	401-1104	Inconel 600	J	28
	401-2104	Inconel 600	K	28
	401-5104*	Inconel 600	R	30
	401-6104*	Inconel 600	S	30
	402-1104	304 SS	J	28
	402-2104	304 SS	K	28
	402-3104	304 SS	T	28
	402-4104	304 SS	E	28
	403-1104	310 SS	J	28
	403-2104	310 SS	K	28
	404-1104	316 SS	J	28
	404-2104	316 SS	K	28
	415-2104	Inconel 702	K	28
	415-5104*	Inconel 702	R	30
	415-6104*	Inconel 702	S	30
.090" ±.001"	401-2105	Inconel 600	K	25
.125" +.002", -.001"	401-1107	Inconel 600	J	22
	401-2107	Inconel 600	K	22
	401-5107*	Inconel 600	R	24
	401-6107*	Inconel 600	S	24
	402-1107	304 SS	J	22
	402-2107	304 SS	K	22
	402-3107	304 SS	T	22
	402-4107	304 SS	E	22
	403-1107	310 SS	J	22
	403-2107	310 SS	K	22
	404-1107	316 SS	J	22
	404-2107	316 SS	K	22
	404-4107	316 SS	E	22
	411-1107	304L SS	J	22
	413-1107	446 SS	J	22
	413-2107	446 SS	K	22
	415-2107	Inconel 702	K	22
	415-5107*	Inconel 702	R	24
	415-6107*	Inconel 702	S	24
.188" +.002", -.001"	401-1108	Inconel 600	J	19
	401-2108	Inconel 600	K	19
	402-1108	304 SS	J	19
	402-2108	304 SS	K	19
	402-3108	304 SS	T	19
	402-4108	304 SS	E	19
	403-1108	310 SS	J	19
	403-2108	310 SS	K	19
	404-1108	316 SS	J	19
	404-2108	316 SS	K	19

All platinum element XacTpak material is provided to the IPTS-1948 curve unless the IPTS-1968 curve is specifically requested.

Shipping and Packaging

Bulk XacTpak is stocked in random lengths from 8 ft. to "Maximum Stock Lengths." We reserve the right to supply random lengths of our choice unless specific cut lengths are specified on your order.

Single Element

Sheath O.D.	Catalog Number	Sheath Material	ANSI Calibration	Nominal B. & S. Gauge
.250" +.003", -.001"	401-1111	Inconel 600	J	16
	401-2111	Inconel 600	K	16
	402-1111	304 SS	J	16
	402-2111	304 SS	K	16
	402-3111	304 SS	T	16
	402-4111	304 SS	E	16
	403-1111	310 SS	J	16
	403-2111	310 SS	K	16
	404-1111	316 SS	J	16
	404-2111	316 SS	K	16
	413-1111	446 SS	J	16
	413-2111	446 SS	K	16
.313" +.003", -.001"	401-1112	Inconel 600	J	14
	401-2112	Inconel 600	K	14
.375" +.003", -.002"	401-2113	Inconel 600	K	13
	402-1113	304 SS	J	13
.500" +.003", -.001"	401-2115	Inconel 600	K	10

Double Element—Adjacent Conductors

Sheath O.D.	Catalog Number	Sheath Material	ANSI Calibration	Nominal B. & S. Gauge
.063" ±.001"	401-2104-050	Inconel 600	K	30
	404-1104-050	316 SS	J	30
	404-3104-050	316 SS	T	30
.125" +.002", -.001"	401-2107-050	Inconel 600	K	24
	402-1107-050	304 SS	J	24
	402-4107-050	304 SS	E	24
	404-1107-050	316 SS	J	24
	404-3107-050	316 SS	T	24
.188" +.002", -.001"	401-2108-050	Inconel 600	K	21
	402-1108-050	304 SS	J	21
	402-4108-050	304 SS	E	21
.250" +.003, -.001"	401-2111-050	Inconel 600	K	18
	402-1111-050	304 SS	J	18
	402-2111-050	304 SS	K	18

Double Element—Diagonal Conductors

.063" ±.001"	401-2104-001	Inconel 600	K	30
	404-1104-001	316 SS	J	30
	404-3104-001	316 SS	T	30
.125" +.002", -.001"	401-2107-002	Inconel 600	K	24
	404-1107-001	316 SS	J	24
	404-3107-001	316 SS	T	24

Dimensions

Sheath O.D.	Nominal Wall Thickness	Maximum Stock Length	Sheath O.D.	Nominal Wall Thickness	Maximum Stock Length
.010"	.0015"	50 ft	.125"	.017"	375 ft
.020"	.003"	100 ft	.188"	.025"	175 ft
.032"	.004"	150 ft	.250"	.033"	100 ft
.040"	.006"	200 ft	.313"	.041"	60 ft
.063"	.009"	500 ft	.375"	.052"	45 ft
.090"	.012"	375 ft	.500"	.070"	30 ft

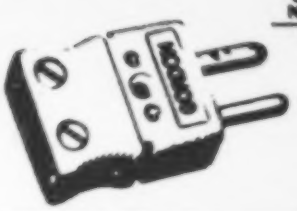
Normally, bulk XacTpak is furnished as follows:

Size .010" O.D. ..... Spooled
Sizes .020" O.D. to .040" O.D. ..... 9" diameter coils
Sizes .063" O.D. to .313" O.D. ..... 24" diameter coils
Sizes .375" O.D. to .500" O.D. ..... Straight lengths of 35 ft. or less

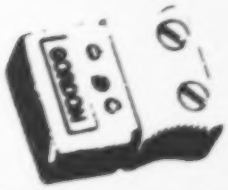
On request, bulk XacTpak can be furnished in other coil dimensions or shipped in straight form when necessary.

Standard Thermocouple Connectors

Outstanding Features Lightweight, rugged, accurate • Quick positive wiring hookup • Exclusive channel design isolates all wire for clean, strong signals • Matching thermocouple materials throughout (except Type R/S, which are compensated) • Hollow pins minimize weight • Standard 7/16" pin spacing • Glass-filled thermoplastic provides high impact strength • Fully visible connections • ANSI color coded • Excellent for high temperature thermocouple applications, 400° F (204° C) ambient temperature rating • Molded-in threaded inserts • Captive cap screws won't fall out



Catalog Number	Description
900	Connector Plug with Gordon name (Specify Calibration*)
910†	Connector Plug without Gordon name† (Specify Calibration*)



Catalog Number	Description
901	Connector Jack (Specify Calibration*)
911†	Connector Jack without Gordon name† (Specify Calibration*)

Catalog Number	Description
924	Connector Lock

Catalog Number	Description
923 020 923 032 923 040 923 063 923 125 923 188	Small XacTpak Brazing Adapter for Plug or Jack (Suffix is Sheath O D)

Catalog Number	Description
931-063 931-125 931-188 931-250	Compression Type Adapter for Plug or Jack (Suffix is Sheath O D)

Catalog Number	Description
932-125 932-188 932-250	Large XacTpak Brazing Adapter for Plug or Jack (Suffix is Sheath O D)

Catalog Number	Description
921	Cable Clamp for Plug or Jack

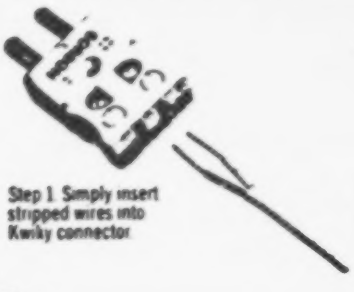
Catalog Number	Description
932-265	Large Brazing Adapter for Flexible Stainless Steel Tubing (.265" O D)

*Available in ANSI calibration types J, K, T, R, S, E and Cu-Cu
†Can be imprinted with customer's own logo (minimum order and tooling charge applies)

Nominal dimensions of plug or jack 1⅜ x 1 x ⅝

Kwiky™ Thermocouple Connectors

Time-saving Kwiky thermocouple connectors are fast and convenient to use. No loose parts, no cap removal, no need to wrap wires around terminal screws. Simply insert stripped wire ends into plug or jack, tighten down two terminal screws, and you're finished. No need to remove Gordon cable clamp, either. Accepts solid or stranded wires to 16 gauge. Available in J or K calibrations, ANSI color-coded. The connector is made of a high impact strength, 400° F (205° C) rated glass filled thermoplastic with matching thermocouple materials throughout. Other features and specifications are identical to standard Gordon 900 Series quick disconnect connectors.



Step 1. Simply insert stripped wires into Kwiky connector.

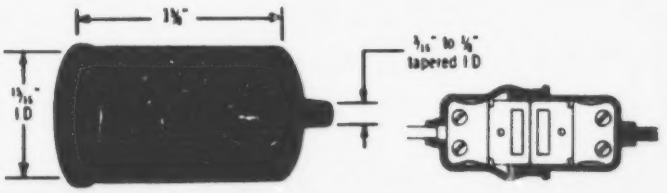
Step 2. Tighten down two terminal screws, and you're finished.

Catalog Number	Description	Catalog Number	Description
916	Kwiky Connector Plug with Gordon name (specify J or K calibration)	917	Kwiky Connector Jack with Gordon name (specify J or K calibration)
918	Kwiky Connector Plug without Gordon name* (specify J or K calibration)	919	Kwiky Connector Jack without Gordon name* (specify J or K calibration)

* Can be imprinted with customer's own logo (minimum order and tooling charge applies)

Weatherproof Boots Catalog Number 943

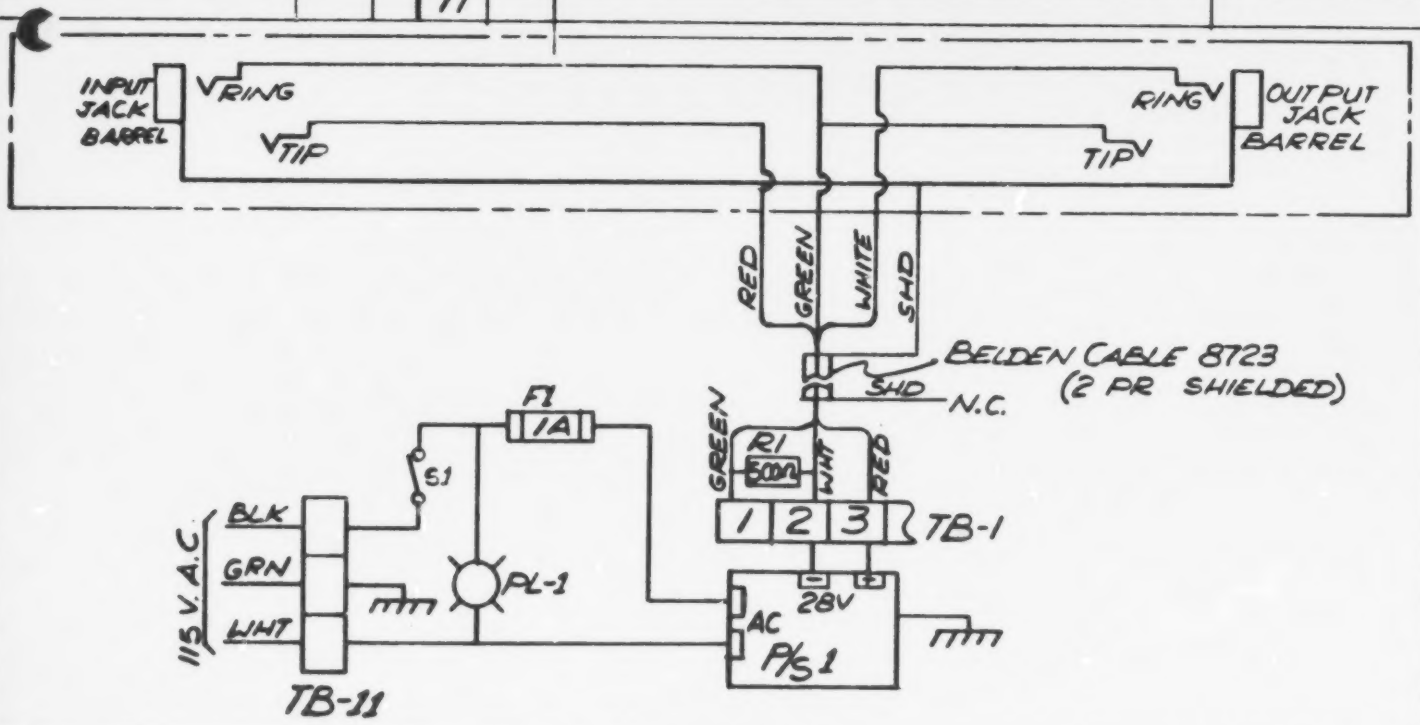
Used in pairs as illustrated, these flexible Neoprene rubber boots add moisture protection to standard plug-to-jack connections. Individually, they can also be used over our TH-2723 or TH-2724 canister type heads.



SCALE	5902 A 69	Westinghouse Canada Inc. TITLE ROSEMOUNT TRANSMITTER SIGNAL CONDITIONER.

ALL DIMENSIONS IN INCHES | FOR IMPLIED TOLERANCES SEE MANUFACTURING STANDARD | DIVISION

ITEM	REFERENCE No.	DESCRIPTION	IDENTIFICATION
1	F1	BUSS AGC1 FUSE	
2	PL-1	I.D.I. INDICATOR #1050QC3 (125 V.AC/AMBER)	
3	P/S 1	HAMMOND HPFS028008 P/S	
4	S1	J.B.T. JMT-121 SWITCH OR EQUIV.	
5	R1	GENERAL RESISRANCE - BEIGE - 500Ω ± .025%	
6	TB-1	CINCH 12-140 - 3/4W TERM. BLOCK.	
7	TB-11	CINCH 3-142 TERM. BLOCK.	
8	FH	FUSE HOLDER - BUSS 5823-6	
9	CH	CHASSIS #1441-3	
10	PC	POWER CORD 9' - BELDEN 17419	
11			



NOTES: 1) ALL CHASSIS WIRING AWG #22.

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SPECIFICATION FOR CONTROL ROOM

DIMENSIONS:		≈ 8'x8'x8'
TYPE	:	Wood frame construction fabricated to minimize ingress of dust particles.
FLOOR	:	Self supporting. Finished with floor tile.
WALLS	:	Panel (at discretion of user). Insulated, minimum R10.
CEILING	:	Acoustic tile. Insulated, minimum R10. Access port for signal wires.
MSC.	:	Standard 36" wide door with automatic closer. Lighting (to suit user). Opening for air conditioner.

APPENDIX IV

WESTINGHOUSE SOFTWARE PROGRAM - CWCD-021

WESTINGHOUSE CANADA INC.
NUCLEAR PRODUCTS DEPARTMENT

COMPUTER DOCUMENTATION - CWCD-021

HOST COMPUTER SOFTWARE FOR CONTROL OF A 450 TON HYDRAULIC RAM

JUNE 1985

PREPARED BY: F.B. RUSSELL

DISTRIBUTION:

E.R.C. AYERS	WECAN - BR3
R.C. HAYES	WECAN - BR3
F. STERN	WECAN - BR3

1. INTRODUCTION

This document describes the software written for the controlling of a 450 ton hydraulic ram. Written in Fortran and designed to run on a minicomputer, this supervisory program allows the press operator to select the desired sample strain rate, select the initial starting hydraulic conditions, sample and display the instrumentation signals, as well as initiate the action of the press. Alarm (GO/NO GO) conditions are built into the program to prevent premature press initiation. Feedback control of the press ram displacement is achieved by first precalculating the control valve stroke then downloading it to a microprocessor based feedback controller. Detailed in this document are the supervisory program features,as well as flow charts and coding.

2. PROGRAM FEATURES

The supervisory program is a disk based data acquisition, control and storage program. All the information needed to control the actions of the press for any particular sample history is stored in a 'header record' disk file. On startup of the program, the user has the choice of either using one of the previous histories or inputting new conditions to define a new history. The program then steps the operator through a series of program options by prompting a series of questions needed to define the test conditions. Any of the eleven basic program options can be selected from a menu. Sample sessions from each of these options is included later in this document.

By prompting the user to input the sample geometry, desired strainrate and maximum deformation, the sample height as a function of time can be computed. This also specifies the ram position and velocity, as well as the hydraulic fluid flow requirements. Knowledge of the flow control valve behaviour (flow = f(stroke, pressure drop)), along with the system characteristics (accumulator depressurization, line losses), and the sample's estimated yield strength, the control valve stroke as a function of time can be specified. The software performs these calculations while ensuring that the correct valves are selected, that the control valve stoke is in an acceptable range, and that the correct accumulator pressure is selected.

Once all the sample and press parameters and options have been selected, the operator selects the scan data / mini menu feature. While in this mode, the program samples and displays all the instrumentation signals so the operator is aware of hydraulic system status (pressure, temperature, valve positions), and the billet temperature. When the operator decides to initiate the action, the computer checks a series of 16 go/no go conditions. If any of these checks indicate the no go condition, the press will not start. Once all these conditions are cleared, the host program downloads the required information to the controller. Action will only start after the operator enters a 'GO' command. While in the control loop, two other data acquisition modules will gather the instrumentaion signals and return them to the host computer at the end of the event for storage and post test processing.

In the following sections, sample sessions for each program option is provided. Flowcharts for each option are provided in Figures 1A through 1K, while a compiled listing is presented in Appendix I.

3. SAMPLE SESSION

The supervisory program main menu is given below. Options 1 through 7, 8 and 9 are executed when the program is started up. Option 7 can be previewed at any time to review the status of the go/no go conditions, but the user is forced through it before initiation of the press action.

```
##################
### MAIN MENU ###
##################

1. Open Disk File              7.  Alarm Conditions
2. Test label                  8.  Offset voltages
3. Channel assignments         9.  Test description
4. Press control parameters    10. END PROGRAM
5. Rates and periods           11. Scan Data - MINI MENU
6. Calculate displacement

        Enter option ... _
```

The mini menu (main menu option 11) is shown below. In this option all instrumentation readings are sampled and displayed approximately every 10 seconds. Selection of option 1 will return control to the main menu. Option 2 will provide a hard copy of the mini menu display of the engineering units and voltages. Option 3, start of the press action, will first force control through main menu option 7. If any of the alarm conditions have the no go status, control will return to the mini menu. If all conditions are clear, the the download procedure will start. The operator is then asked to confirm starting of the press.

```
>              HYDRAULIC PRESS CONTROL - MINI MENU
                Exit    Print     Initiate Control
                 1        2              3

    Date: 1985  JUNE  17
    Test: SAMPLE RUN                                  Time: 13:18:49.85

          H Y D R A U L I C   P R E S S   S U P E R V I S O R

    Engineering Units

.00000 .01001 .02000 .03000 .04000 .05000 .06000 .07000 .08000 .09000
.10001 .11000 .12000 .13000 .14000 .15000 .16000 .17000 .18000 .00000
1.2000 1.2100 1.2200 1.2300 1.2400 1.2500 1.2600 1.2700 .00000 .00000
1.3000 1.3100 1.3200 1.3300 .00000 .00000 .00000 1.3700 .00000 .00000
678.18 608.57 682.62 684.61 686.76 688.90 691.04 693.19 695.33 697.47

2.5000 2.5100 2.5200 2.5300 2.5400 2.5500 2.5600 2.5700 2.5800 3.5900
3.6000 3.6100 3.6200 3.6300 3.6400

    Voltages

.00000 .01001 .02000 .03000 .04000 .05000 .06000 .07000 .08000 .09000
.10001 .11000 .12000 .13000 .14000 .15000 .16000 .17000 .18000 1.1900
1.2000 1.2100 1.2200 1.2300 1.2400 1.2500 1.2600 1.2700 1.2800 1.2900
1.3000 1.3100 1.3200 1.3300 1.3400 1.3500 1.3600 1.3700 1.3800 2.3900
2.4000 2.4100 2.4200 2.4300 2.4400 2.4500 2.4600 2.4700 2.4800 2.4900

2.5000 2.5100 2.5200 2.5300 2.5400 2.5500 2.5600 2.5700 2.5800 3.5900
3.6000 3.6100 3.6200 3.6300 3.6400
```

3.1 OPTION 1: DISK FILE OPEN

In this and the next sections, sample sessions are provided. Although many of the coding details pertain to Hewlett Packard computers, it is anticipated that the conversion to other minicomputer operating systems will not be a difficult procedure.

Option 1 sample session

```
File for A,B,C's, offsets, etc


Disk cartridge number  [34] ...

File name - <HDP[00]:Sc:34 or [EX]it
Change      <HDP_

File <HDP00::34:: 3328 - open

File <HDP00::34 - closed

Disk file test: SAMPLE RUN          Ran: 1985  JUNE  17

Today is: 1985  JUNE  17    Time is now: 13:28: 1.44  ...

Test Label

Edit Test Label (cr nc; / nc; ! truncate)

SAMPLE RUN          >_
```

3.2 OPTION 2: TEST LABEL

In this option the current test label is displayed. The user can hit return to leave it unchanged, re-enter it completely, or edit the current label character by character.

Option 2 sample session

```
Test Label

Edit Test Label (cr nc; / nc; ! truncate)

SAMPLE RUN        >_
```

3.3 OPTION 3: CHANNEL ASSIGNMENTS

In this section, the channel description, conversion constants, scanner choice and scanner channel assignments can be reviewed and modified if desired.

Option 3 sample session

```
Channel Assignments

Number of constant changes ... 1

First and last display channels =    1 100 ... 1,20
```

D A T A A C Q U I S I T I O N C O N S T A N T S

DATE: 1985 JUNE 17 TEST: SAMPLE RUN TIME: 14: 0: 9:13

CH	FUNCTION		A	B	C	SCNR	CHAN
1	LC1	FORCE ON BILLET	0.000000	1.000000	0.000000	2	1
2	LC2	FORCE ON BILLET	0.000000	1.000000	0.000000	2	2
3	LC3	FORCE ON BILLET	0.000000	1.000000	0.000000	2	3
4	LC4	FORCE ON BILLET	0.000000	1.000000	0.000000	2	4
5	LVDT	RAM POSITION	0.000000	1.000000	0.000000	1	1
6	PT1	ACCUMULATOR OIL PRESSURE	0.000000	1.000000	0.000000	2	5
7	PT2	LOW FLOW POPPET DSTR PRESS	0.000000	1.000000	0.000000	2	6
8	PT3	HIGH FLOW POPPET DSTR PRES	0.000000	1.000000	0.000000	2	7
9	PT4	PRESS INLET PRESSURE	0.000000	1.000000	0.000000	1	2
10	PT5	PRESS OUTLET PRESSURE	0.000000	1.000000	0.000000	2	8
11	PT6	ACCUMULATOR AIR PRESSURE	0.000000	1.000000	0.000000	2	9
12	SG1	STRAIN DIE	0.000000	1.000000	0.000000	2	10
13	SG2	STRAIN DIE	0.000000	1.000000	0.000000	2	11
14	SG3	STRAIN PRESS-NEW	0.000000	1.000000	0.000000	2	12
15	SG4	STRAIN PRESS-NEW	0.000000	1.000000	0.000000	2	13
16	SG5	STRAIN PRESS-NEW	0.000000	1.000000	0.000000	2	14
17	SG6	STRAIN PRESS-OLD	0.000000	1.000000	0.000000	2	15
18	SG7	STRAIN PRESS-OLD	0.000000	1.000000	0.000000	2	16
19	SG8	STRAIN PRESS-OLD	0.000000	1.000000	0.000000	2	17
20		SPARE	0.000000	0.000000	0.000000	0	0

```
Line editor available for descriptions

Change # 1
Channel # ... [  1] ... 11

                                        A          B          C
Reduction constants ( 11) 0.000000  1.000000  0.0000000
                          101.325

                                     Scanner   Channel
Control constants   ( 11)              2         9

Description         ( 11) PT6   ACCUMULATOR AIR PRESSURE

Ch ( 11) PT6   ACCUMULATOR AIR PRESSURE    101.3250  1.000000  0.000000   2   9

Hard copy of new constants [Y/N] N

Constants correct ? [Y/N] Y          (if N is selected, option is
                                      restarted)
```

3.4 OPTION 4: PRESS CONTROL PARAMETERS

Under this option the user can review the billet sample geometry, desired strain rate, maximum deformation, number of valves, estimated yield strength, etc..

```
### Option 4 sample session ###

Press Control Parameters

Sample cross section area (in2)     [5.3000] ...
Sample height             (in)      [5.0000] ...
Nominal strain rate       (sec-1)   [3.5000] ...
Maximum deformation       (in)      [2.0000] ...

   4 valves now selected; No.s  3,  4,  5,  6,

   4 valves must be used; suggest no.s  3,  4,  5,  6

Use suggested valves    [Y/N] ... Y      (if N selected; valves can
                                          user specified)
```

```
   Event expected to last  .1460 seconds

Start lead time           (sec)    [.00000] ...
End   lead time           (sec)    [1.0000] ...

Feedback error factor Kh1          [1.0000] ...
Feedback error factor Kh2          [1.0000] ...
Feedback error factor Kh3          [1.0000] ...

Feedback error factor K11          [1.0000] ...
Feedback error factor K12          [1.0000] ...
Feedback error factor K13          [1.0000] ...

Yield strength estimate   (psi)    [130000] ...
Line loss estimate        (psi)    [20.000] ...

   3428. psi required to yield specimen estimated
   1052. psi head available to drive ram


Die  strain threshold     (uin/in) [500.00] ...
Bolt strain threshold     (uin/in) [500.00] ...
```

3.5 OPTION 5: RATE AND PERIOD

The total event time can be calculated from the entered strainrate and deformation limits. The scan rate in the fast scanning modules is limited to 2 ms, and since the internal memory is fixed , we are limited to 1024 samples during the event. If a slower strainrate is selected such that the total event time is greater than 2.048 seconds, then the scan rate has to be slowed down so that the whole event may be captured. Under this option, the time parameters are displayed (there are no inputs required).

Option 5 sample session

```
Time step Calculation


Control loop overall time:   .14595 seconds
Cycle time / scan rate    :  .00200 seconds
Number of time steps      :  73.000   ... >
```

3.6 OPTION 6: CALCULATE DISPLACEMENT

The required ram displacement and velocity can be computed from the parameters enter under option 4. The hydraulic fluid flow rate is first displayed, then questions concerning the initial flow control valves are prompted. The calculated stroke is then displayed. If the computed stroke exceeds 100 % then a warning is issued and correcting action suggested.

Option 6 sample session

Displacement & stroke calculation

Oil Flow Requirements

Step #	Time sec	Smpl Hght inches	Ram Pos inches	Ram Vel in/sec	Oil Flow L/min
1	0.0000	5.0000	0.0000	17.500	864.6
3	.0040	4.9305	.0695	17.257	852.6
5	.0080	4.8619	.1381	17.017	840.8
7	.0120	4.7944	.2056	16.780	829.1
9	.0160	4.7277	.2723	16.547	817.5
11	.0200	4.6620	.3380	16.317	806.2
13	.0240	4.5972	.4028	16.090	795.0
15	.0280	4.5332	.4668	15.866	783.9
17	.0320	4.4702	.5298	15.646	773.0
19	.0360	4.4081	.5919	15.428	762.3
21	.0400	4.3468	.6532	15.214	751.7
23	.0440	4.2864	.7136	15.002	741.2
25	.0480	4.2268	.7732	14.794	730.9
27	.0520	4.1680	.8320	14.588	720.8
29	.0560	4.1101	.8899	14.385	710.7
31	.0600	4.0529	.9471	14.185	700.9
33	.0640	3.9966	1.0034	13.988	691.1

... >

Oil Flow Requirements

Step #	Time sec	Smpl Hght inches	Ram Pos inches	Ram Vel in/sec	Oil Flow L/min
35	.0680	3.9410	1.0590	13.794	681.5
37	.0720	3.8862	1.1138	13.602	672.0
39	.0760	3.8322	1.1678	13.413	662.7
41	.0800	3.7789	1.2211	13.226	653.5
43	.0840	3.7264	1.2736	13.042	644.4
45	.0880	3.6746	1.3254	12.861	635.4

```
 47    .0920     3.6235     1.3765     12.682      626.6
 49    .0960     3.5731     1.4269     12.506      617.9
 51    .1001     3.5234     1.4766     12.332      609.3
 53    .1040     3.4745     1.5255     12.161      600.8
 55    .1080     3.4262     1.5738     11.992      592.5
 57    .1120     3.3785     1.6215     11.825      584.2
 59    .1160     3.3316     1.6684     11.660      576.1
 61    .1200     3.2852     1.7148     11.498      568.1
 63    .1240     3.2396     1.7604     11.338      560.2
 65    .1280     3.1945     1.8055     11.181      552.4
 67    .1320     3.1501     1.8499     11.025      544.7
 69    .1360     3.1063     1.8937     10.872      537.2

... >
 Oil Flow Requirements

Step   Time    Smpl Hght   Ram Pos    Ram Vel    Oil Flow
 #      sec     inches      inches     in/sec      L/min

 71    .1400     3.0631     1.9369     10.721      529.7
 73    .1440     3.0205     1.9795     10.572      522.3

... >

 Maximum oil flow required is 864.6 litres/min
 Minimum oil flow required is 518.8 litres/min


... >

 Initial stroke position [85.00] ...

 Initial control valve pressure drop must be
 greater than 747.9 but less than 1052. psi.

 Enter initial value ... [747.9] ...

 Set accumulator pressure to 4196. psi

 Enter gas volume in accumulator (us gal) [12.5] ...

 Will the accumulator be isolated [Y/N] ... Y

 Oil Flow Requirements and Depressurization Predictions

Step   Time    Smpl Hght   Ram Pos    Ram Vel    Oil Flow   Stroke   Acc Pres   DPval
 #      sec     inches      inches     in/sec      L/min       %        psi       psi

  1  0.0000     5.0000     0.0000     17.500      864.6     85.000    4196.     747.9
  3    .0040    4.9305      .0695     17.257      852.6     84.984    4176.     727.7
  5    .0080    4.8619      .1381     17.017      840.8     84.971    4156.     708.0
  7    .0120    4.7944      .2056     16.780      829.1     84.961    4137.     688.7
  9    .0160    4.7277      .2723     16.547      817.5     84.954    4118.     669.9
 11    .0200    4.6620      .3380     16.317      806.2     84.950    4099.     651.5
 13    .0240    4.3972      .4028     16.090      795.0     84.950    4081.     633.5
```

15	.0280	4.5332	.4668	15.866	783.9	84.954	4064.	615.9
17	.0320	4.4702	.5298	15.646	773.0	84.962	4047.	598.7
19	.0360	4.4081	.5919	15.428	762.3	84.975	4030.	581.9
21	.0400	4.3468	.6532	15.214	751.7	84.992	4013.	565.4
23	.0440	4.2864	.7136	15.002	741.2	85.015	3997.	549.3
25	.0480	4.2268	.7732	14.794	730.9	85.042	3981.	533.6
27	.0520	4.1680	.8320	14.588	720.8	85.075	3966.	518.2
29	.0560	4.1101	.8899	14.385	710.7	85.114	3951.	503.1
31	.0600	4.0529	.9471	14.185	700.9	85.160	3936.	488.4
33	.0640	3.9966	1.0034	13.988	691.1	85.212	3922.	474.0

... >

Oil Flow Requirements and Depressurization Predictions

Step #	Time sec	Smpl Hght inches	Ram Pos inches	Ram Vel in/sec	Oil Flow L/min	Stroke %	Acc Prss psi	DPval psi
35	.0680	3.9410	1.0590	13.794	681.5	85.271	3908.	459.8
37	.0720	3.8862	1.1138	13.602	672.0	85.337	3894.	446.0
39	.0760	3.8322	1.1678	13.413	662.7	85.411	3880.	432.5
41	.0800	3.7789	1.2211	13.226	653.5	85.494	3867.	419.2
43	.0840	3.7264	1.2736	13.042	644.4	85.585	3854.	406.2
45	.0880	3.6746	1.3254	12.861	635.4	85.686	3841.	393.5
47	.0920	3.6235	1.3765	12.682	626.6	85.797	3829.	381.0
49	.0960	3.5731	1.4269	12.506	617.9	85.918	3817.	368.8
51	.1001	3.5234	1.4766	12.332	609.3	86.050	3805.	356.8
53	.1040	3.4745	1.5255	12.161	600.8	86.194	3793.	345.1
55	.1080	3.4262	1.5738	11.992	592.5	86.350	3781.	333.6
57	.1120	3.3785	1.6215	11.825	584.2	86.520	3770.	322.4
59	.1160	3.3316	1.6684	11.660	576.1	86.704	3759.	311.3
61	.1200	3.2852	1.7148	11.498	568.1	86.903	3748.	300.5
63	.1240	3.2396	1.7604	11.338	560.2	87.118	3738.	289.9
65	.1280	3.1945	1.8055	11.181	552.4	87.351	3727.	279.5
67	.1320	3.1501	1.8499	11.025	544.7	87.601	3717.	269.3
69	.1360	3.1063	1.8937	10.872	537.2	87.872	3707.	259.2

... >

Oil Flow Requirements and Depressurization Predictions

Step #	Time sec	Smpl Hght inches	Ram Pos inches	Ram Vel in/sec	Oil Flow L/min	Stroke %	Acc Prss psi	DPval psi
71	.1400	3.0631	1.9369	10.721	529.7	88.164	3697.	249.4
73	.1440	3.0205	1.9795	10.572	522.3	88.479	3688.	239.8

... >

3.7 OPTION 7: ALARM CONDITIONS

The option can be previewed at any time from the main menu, and will be executed from the mini menu when the request to initiate the press action is given. If there are any alarms to be resolved, such as valve openings or closings, they must be resolved before the press control can take place.

```
### Option 7 sample session ###

          Alarm Conditions

TC2 upper limit  120 F          - now 608.57 : condition is NO GO ... >
PT6 upper limit 4500 psi        - now 101.43 : condition is    GO ... >
VA7    VALVE NO.7 STATUS          now   2.56 : condition is NO GO ... >
VA8    VALVE NO.8 STATUS          now   2.57 : condition is NO GO ... >
VA9    VALVE NO.9 STATUS          now   2.58 : condition is NO GO ... >
VA12   VALVE NO.12 STATUS         now   3.59 : condition is NO GO ... >
VA13   VALVE NO.13 STATUS         now   3.60 : condition is NO GO ... >
VA14   VALVE NO.14 STATUS         now   3.61 : condition is NO GO ... >
VA15   VALVE NO.15 STATUS         now   3.62 : condition is NO GO ... >
VA16   VALVE NO.16 STATUS         now   3.63 : condition is NO GO ... >
VA17   VALVE NO.17 STATUS         now   3.64 : condition is NO GO ... >
SG1    STRAIN DIE                 now    .11 : condition is    GO ... >
SG2    STRAIN DIE                 now    .12 : condition is    GO ... >
SG3    STRAIN PRESS-NEW           now    .13 : condition is    GO ... >
SG4    STRAIN PRESS-NEW           now    .14 : condition is    GO ... >
SG5    STRAIN PRESS-NEW           now    .15 : condition is    GO ... >

 10 alarm conditions must be resolved !!   >

Offset voltage confirmation

Ch  Description                          Offset   Value

 1 LC1   FORCE ON BILLET                 .00000  .00000
 2 LC2   FORCE ON BILLET                 .00000  .01001
 3 LC3   FORCE ON BILLET                 .00000  .02000
 4 LC4   FORCE ON BILLET                 .00000  .03000
 6 PT1   ACCUMULATOR OIL PRESSURE        .00000  .05000
 7 PT2   LOW FLOW POPPET DSTR PRESS      .00000  .06000
 8 PT3   HIGH FLOW POPPET DSTR PRES      .00000  .07000
 9 PT4   PRESS INLET PRESSURE            .00000  .08000
10 PT5   PRESS OUTLET PRESSURE           .00000  .09000
11 PT6   ACCUMULATOR AIR PRESSURE        .00000  101.43

Want to revise these offsets ? [Y/N] ... N
```

3.8 OPTION 8: OFFSET VOLTAGES

The option should be run to record the offset voltages for each instrumentation channel. Typically, a pressure transmitter will have a non zero voltage output when the transducer is equalized which must be subtracted off all subsequent readings. This option is designed to display and allow flexibility in recording channel offset voltages.

Option 8 sample session

```
Offset voltages


.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000

.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000

Offsets menu:

   1: keep current offsets          4: by range
   2: zero all offsets              5: by channel
   3: take all channel offsets

   enter option                      [1] ... 4

Enter first and last channel  [  1,100] ... 22,24

Offset voltages


.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 1.2100 1.2200 1.2300 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000


.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
.00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000 .00000
```

```
Offset voltages satisfactory [Y/N] ... Y
```

3.9 OPTION 9: TEST DESCRIPTION

In this option the current test description is displayed. There are five 72 character lines available to describe the test. All 5 lines are first displayed, then each line is displayed giving the user a chance to hit return to leave it unchanged, re-enter it completely, or edit the current line character by character.

Option 9 sample session

```
   Sample Description

SAMPLE SPECIMEN # 10
HIGH STRENGTH STEEL
AMBIENT TEMPERATURE
ESTIMATED YIELD STRENGTH 130,000 PSI
COMMISSIONING RUN

Edit description (cr nc; / nc; ! truncate)

SAMPLE SPECIMEN # 10
>
HIGH STRENGTH STEEL
>
AMBIENT TEMPERATURE
>
ESTIMATED YIELD STRENGTH 130,000 PSI
>
COMMISSIONING RUN
>


Description

SAMPLE SPECIMEN # 10
HIGH STRENGTH STEEL
AMBIENT TEMPERATURE
ESTIMATED YIELD STRENGTH 130,000 PSI
COMMISSIONING RUN
```

3.10 OPTION 10: END PROGRAM

Before exitting the program, the user is asked if the current parameters for this session are to be saved by rewriting (revising) over the original file, or in a new file. If a new file is to be used, then the user must enter a new unique file name to store the current parameters.

Option 10 sample session

```
Store current information on original file [Y/N] ... Y

File <HDP00::34:: 3328 - written and closed
```

3.11 OPTION 11: MINI MENU - INITIATE EVENT

This example shows the terminal display when option 3 in the mini menu is selected. For this case, all go/no go conditions were simulated to be in the go condition.

Option 11 sample session

```
>3          HYDRAULIC PRESS CONTROL - MINI MENU
            Exit   Print    Initiate Control
             1       2            3

   Date: 1985  JUNE  17
   Test: SAMPLE RUN                              Time: 13:18:49.85

              H Y D R A U L I C   P R E S S   S U P E R V I S O R


   Alarm Conditions

   TC2 upper limit  120 F        - now  25.57 : condition is    GO ... >
   PT6 upper limit 4500 psi      - now 101.43 : condition is    GO ... >
   VA7    VALVE NO.7 STATUS        now   0.00 : condition is    GO ... >
   VA8    VALVE NO.8 STATUS        now   0.00 : condition is    GO ... >
   VA9    VALVE NO.9 STATUS        now   0.00 : condition is    GO ... >
   VA12   VALVE NO.12 STATUS       now   0.00 : condition is    GO ... >
```

```
VA13   VALVE NO.13 STATUS          now   0.00 : condition is    GO ... >
VA14   VALVE NO.14 STATUS          now   0.00 : condition is    GO ... >
VA15   VALVE NO.15 STATUS          now   0.00 : condition is    GO ... >
VA16   VALVE NO.16 STATUS          now   0.00 : condition is    GO ... >
VA17   VALVE NO.17 STATUS          now   0.00 : condition is    GO ... >
SG1    STRAIN DIE                  now   0.00 : condition is    GO ... >
SG2    STRAIN DIE                  now   0.00 : condition is    GO ... >
SG3    STRAIN PRESS-NEW            now   0.00 : condition is    GO ... >
SG4    STRAIN PRESS-NEW            now   0.00 : condition is    GO ... >
SG5    STRAIN PRESS-NEW            now   0.00 : condition is    GO ... >

 All alarm conditions cleared for event      >

 Offset voltage confirmation

 Ch  Description                          Offset    Value

  1 LC1   FORCE ON BILLET                 .00000   .00000
  2 LC2   FORCE ON BILLET                 .01001   .00000
  3 LC3   FORCE ON BILLET                 .02000   .00000
  4 LC4   FORCE ON BILLET                 .03000   .00000
  6 PT1   ACCUMULATOR OIL PRESSURE        .05000   .00000
  7 PT2   LOW FLOW POPPET DSTR PRESS      .06000   .00000
  8 PT3   HIGH FLOW POPPET DSTR PRES      .07000   .00000
  9 PT4   PRESS INLET PRESSURE            .08000   .00000
 10 PT5   PRESS OUTLET PRESSURE           .09000   .00000
 11 PT6   ACCUMULATOR AIR PRESSURE        .10001   101.32

 Want to revise these offsets ? [Y/N] ... N


TAURUS: number of valves, valve numbers,feedback constants

... >

TAURUS download stroke starting

TAURUS download stroke:


TAURUS download complete, enter [GO] to initiate press  ... GO

TAURUS started!

... >
```

4. SAMPLE PROFILES

For the conditions used in this example, the computed conditions are plotted in Figures 2 through 7. A second example printout run for the maximum strain rate case (4.09 sec^{-1}) is given in Table 1.

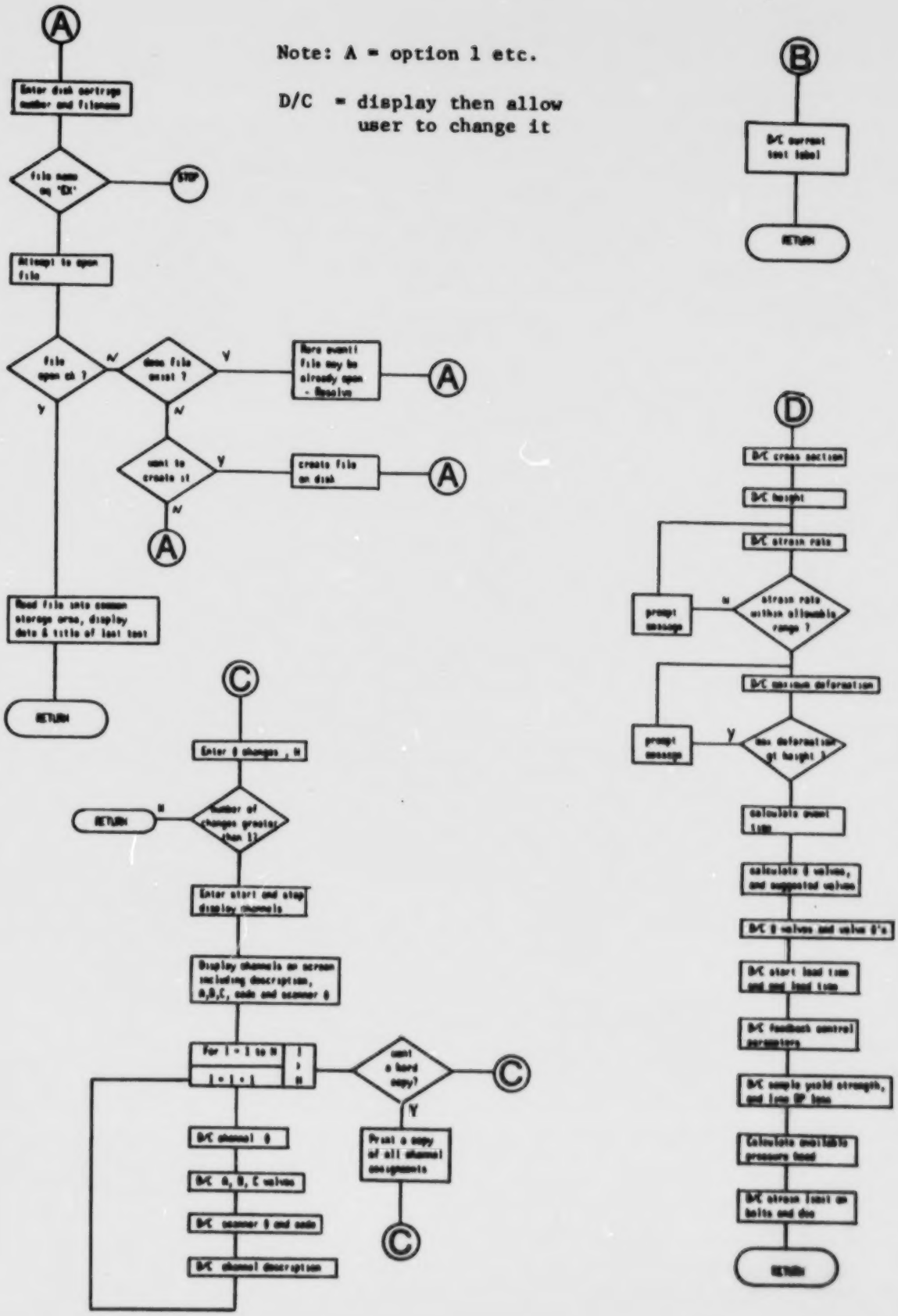
5. FUTURE IMPROVEMENTS

It goes without saying the the refinement of the software cannot be completed until the proposed hardware is constructed and commissioned. At this point some features of the software may appear to be inadequate. An example of this is the yield stress estimate, since it is forseen that it is not a constant but rather a function displacement and/or strainrate. Some other features can be identified now, but cannot be coded until selection of host computer. Some of these features include storage of recalled data from the TAURUS scanners, print, plot and data communications software.

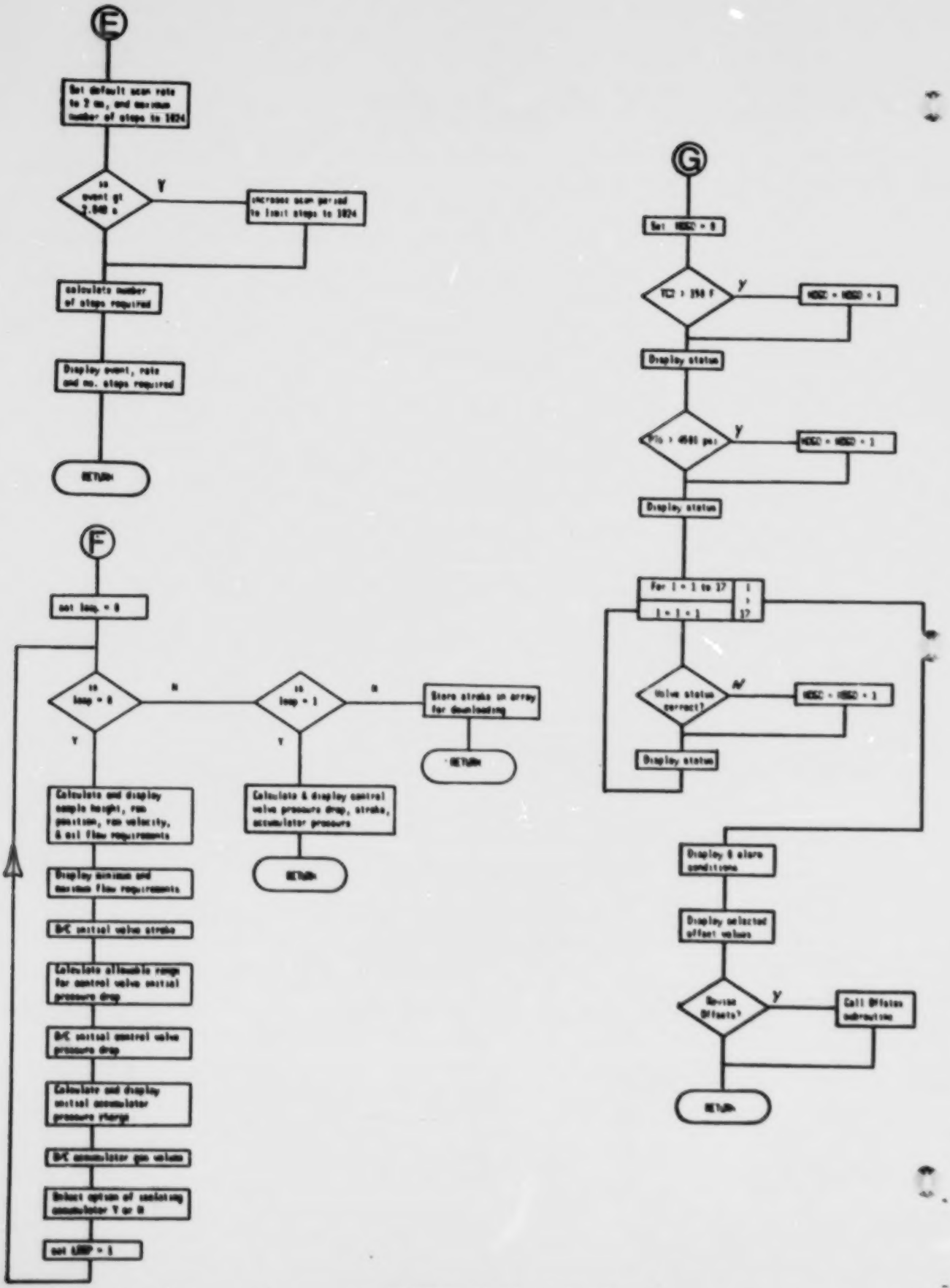
Oil Flow (per valve) Requirements and Depressurization Predictions @ ė=4.09

Step #	Time sec	Spool Hght inches	Rod Pos inches	Rod Vel in/sec	Oil Flow L/min	Stroke %	Acc Pres psi	DPval psi
1	0.0000	5.0000	0.0000	20.450	1010.4	85.000	4469.	1021.
2	.0020	4.9593	.0407	20.283	1002.2	84.898	4457.	1009.
3	.0040	4.9189	.0811	20.118	994.0	84.797	4444.	996.2
4	.0060	4.8788	.1212	19.954	985.9	84.695	4432.	983.9
5	.0080	4.8390	.1610	19.792	977.9	84.592	4420.	971.8
6	.0101	4.7996	.2004	19.630	969.9	84.490	4408.	959.8
7	.0121	4.7605	.2395	19.471	962.0	84.387	4396.	948.0
8	.0141	4.7217	.2783	19.312	954.2	84.285	4384.	936.4
9	.0161	4.6833	.3167	19.155	946.4	84.182	4373.	924.9
10	.0181	4.6451	.3549	18.999	938.7	84.079	4361.	913.6
11	.0201	4.6073	.3927	18.844	931.0	83.975	4350.	902.4
12	.0221	4.5697	.4303	18.690	923.4	83.872	4339.	891.4
13	.0241	4.5325	.4675	18.538	915.9	83.769	4328.	880.5
14	.0261	4.4956	.5044	18.387	908.5	83.665	4318.	869.7
15	.0281	4.4590	.5410	18.237	901.1	83.562	4307.	859.1
16	.0301	4.4226	.5774	18.089	893.7	83.458	4297.	848.6
17	.0321	4.3866	.6134	17.941	886.4	83.355	4286.	838.3
18	.0341	4.3509	.6491	17.795	879.2	83.251	4276.	828.1
19	.0361	4.3154	.6846	17.650	872.1	83.148	4266.	818.0
20	.0381	4.2803	.7197	17.506	864.9	83.044	4256.	808.1
21	.0401	4.2454	.7546	17.364	857.9	82.941	4246.	798.3
22	.0421	4.2108	.7892	17.222	850.9	82.837	4236.	788.6
23	.0441	4.1765	.8235	17.082	844.0	82.734	4227.	779.0
24	.0461	4.1425	.8575	16.943	837.1	82.631	4217.	769.6
25	.0481	4.1087	.8913	16.805	830.3	82.528	4208.	760.2
26	.0501	4.0753	.9247	16.668	823.5	82.424	4199.	751.0
27	.0521	4.0421	.9579	16.532	816.8	82.321	4190.	741.9
28	.0541	4.0091	.9909	16.397	810.2	82.218	4181.	733.0
29	.0561	3.9765	1.0235	16.264	803.6	82.116	4172.	724.1
30	.0581	3.9441	1.0559	16.131	797.0	82.013	4163.	715.3
31	.0601	3.9120	1.0880	16.000	790.5	81.911	4155.	706.7
32	.0621	3.8801	1.1199	15.870	784.1	81.808	4146.	698.1
33	.0641	3.8485	1.1515	15.740	777.7	81.706	4138.	689.7
34	.0661	3.8171	1.1829	15.612	771.4	81.604	4129.	681.3
35	.0681	3.7860	1.2140	15.485	765.1	81.503	4121.	673.1
36	.0701	3.7552	1.2448	15.359	758.8	81.401	4113.	664.9
37	.0721	3.7246	1.2754	15.234	752.7	81.300	4105.	656.9
38	.0741	3.6943	1.3058	15.109	746.5	81.199	4097.	648.9
39	.0761	3.6642	1.3358	14.986	740.4	81.098	4089.	641.1
40	.0781	3.6343	1.3657	14.864	734.4	80.998	4081.	633.3
41	.0801	3.6047	1.3953	14.743	728.4	80.897	4074.	625.7
42	.0821	3.5753	1.4247	14.623	722.5	80.797	4066.	618.1
43	.0841	3.5462	1.4538	14.504	716.6	80.696	4058.	610.6
44	.0861	3.5173	1.4827	14.386	710.8	80.598	4051.	603.2
45	.0881	3.4887	1.5113	14.269	705.0	80.499	4044.	595.9
46	.0901	3.4602	1.5398	14.152	699.2	80.401	4037.	588.7
47	.0921	3.4321	1.5679	14.037	693.5	80.302	4029.	581.5
48	.0941	3.4041	1.5959	13.923	687.9	80.204	4022.	574.5
49	.0961	3.3764	1.6236	13.809	682.3	80.107	4015.	567.5
50	.0981	3.3489	1.6511	13.697	676.7	80.009	4008.	560.6
51	.1001	3.3216	1.6784	13.585	671.2	79.912	4002.	553.8
52	.1021	3.2945	1.7055	13.475	665.7	79.816	3995.	547.0
53	.1041	3.2677	1.7323	13.365	660.3	79.720	3988.	540.4
54	.1061	3.2411	1.7589	13.256	654.9	79.624	3982.	533.8
55	.1081	3.2146	1.7854	13.148	649.6	79.529	3975.	527.3
56	.1101	3.1885	1.8115	13.041	644.3	79.434	3969.	520.9
57	.1121	3.1625	1.8375	12.935	639.1	79.340	3962.	514.5
58	.1141	3.1367	1.8633	12.829	633.9	79.246	3956.	508.2
59	.1161	3.1112	1.8888	12.725	628.7	79.152	3950.	502.0
60	.1181	3.0858	1.9142	12.621	623.6	79.059	3944.	495.8
61	.1201	3.0607	1.9393	12.518	618.5	78.967	3938.	489.8
62	.1221	3.0357	1.9643	12.416	613.5	78.875	3932.	483.7
63	.1241	3.0110	1.9890	12.315	608.5	78.783	3926.	477.8

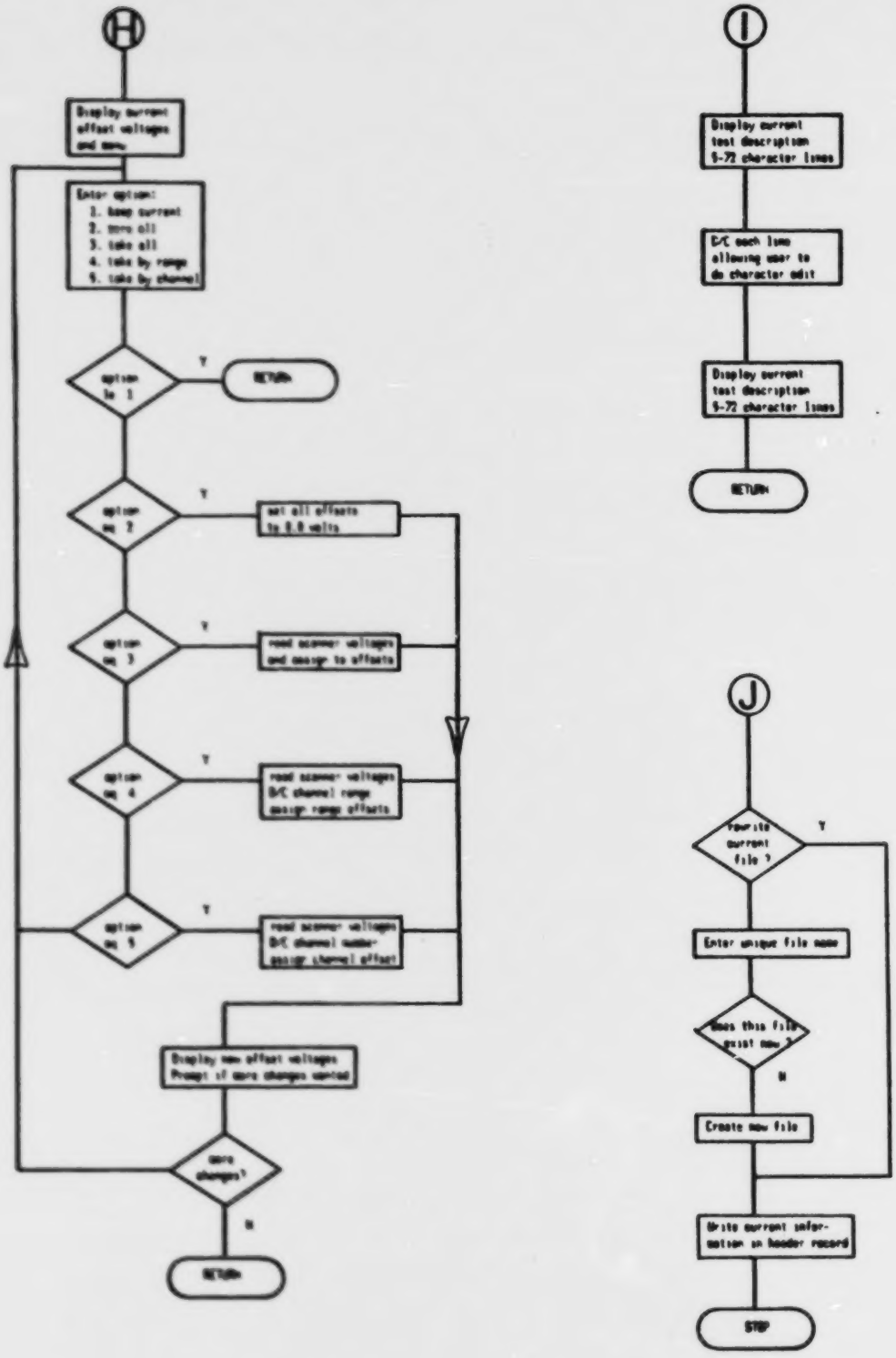
TABLE 1: SAMPLE CALCULATION FOR MAXIMUM STRAIN RATE CASE


Note: A = option 1 etc.
D/C = display then allow user to change it
A
B
C
D
Enter disk cartridge number and filename
file name on 'EX'
STOP
Attempt to open file
file open ok ?
does file exist ?
more event! file may be already open - Resolve
want to create it
create file on disk
Read file into common storage area, display date & title of last test
RETURN
D/C current test label
RETURN
D/C cross section
D/C height
D/C strain rate
prompt message
strain rate within allowable range ?
D/C maximum deformation
prompt message
max deformation at height ?
calculate event time
calculate E values, and suggested values
D/C E values and value E's
D/C start load time and end load time
D/C feedback control parameters
D/C sample yield strength, and time SP here
Calculate available pressure head
D/C strain limit on bolts and die
RETURN
Enter E changes , N
RETURN
Number of changes greater than 1?
Enter start and stop display channels
Display channels on screen including description, A,B,C, scale and scanner #
For I = 1 to N
I = I + 1
want a hard copy?
Print a copy of all channel assignments
D/C channel #
D/C A, B, C values
D/C scanner # and scale
D/C channel description

FIGURES 1A through 1D


E
Set default scan rate to 2 ms, and maximum number of steps to 1024
Is event gt 2.048 s
Y
Increase scan period to limit steps to 1024
Calculate number of steps required
Display event, rate and no. steps required
RETURN
F
Set loop = 0
Is loop = 0
N
Is loop = 1
N
Store stroke in array for downloading
RETURN
Y
Y
Calculate and display sample height, ram position, ram velocity, & oil flow requirements
Calculate & display control valve pressure drop, stroke, accumulator pressure
RETURN
Display minimum and maximum flow requirements
D/C initial valve stroke
Calculate allowable range for control valve initial pressure drop
D/C initial control valve pressure drop
Calculate and display initial accumulator pressure change
D/C accumulator gas volume
Select option of isolating accumulator 1 or 2
Set LOOP = 1
G
Set HOSC = 0
TC2 > 350 F
y
HOSC = HOSC + 1
Display status
Pin > 4500 psi
y
HOSC = HOSC + 1
Display status
For I = 1 to 17
I = I + 1
I > 17
Valve status correct?
N
HOSC = HOSC + 1
Display status
Display & alarm conditions
Display selected offset values
Revise Offsets?
y
Call Offsets subroutine
RETURN

FIGURES 1E through 1G


H
Display current offset voltages and menu
Enter option:
1. Keep current
2. Zero all
3. Take all
4. Take by range
5. Take by channel
option = 1
RETURN
option = 2
set all offsets to 0.0 volts
option = 3
read scanner voltages and assign to offsets
option = 4
read scanner voltages D/C channel range assign range offsets
option = 5
read scanner voltages D/C channel number assign channel offset
Display new offset voltages Prompt if more changes wanted
more changes?
RETURN
I
Display current test description 5-72 character lines
D/C each line allowing user to do character edit
Display current test description 5-72 character lines
RETURN
J
Favorite current file ?
Enter unique file name
Does this file exist now ?
Create new file
Write current information on header record
STOP

FIGURES 1H through 1J

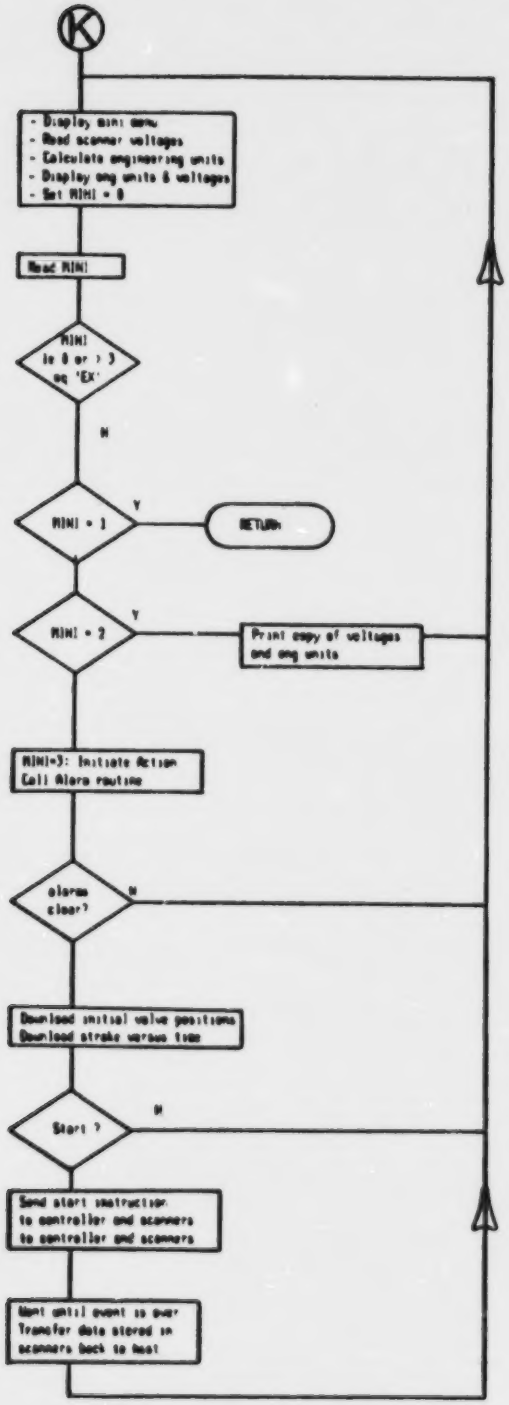

- Display main menu
- Read scanner voltages
- Calculate engineering units
- Display eng units & voltages
- Set MINI = 0
Read MINI
MINI is 0 or > 3 eq 'EX'
N
MINI = 1
Y
RETURN
MINI = 2
Y
Print copy of voltages and eng units
MINI=3: Initiate Action
Call Alarm routine
alarm clear?
N
Download initial valve positions
Download stroke versus time
Start ?
N
Send start instruction to controller and scanners
to controller and scanners
Wait until event is over
Transfer data stored in scanners back to host

FIGURE 1K

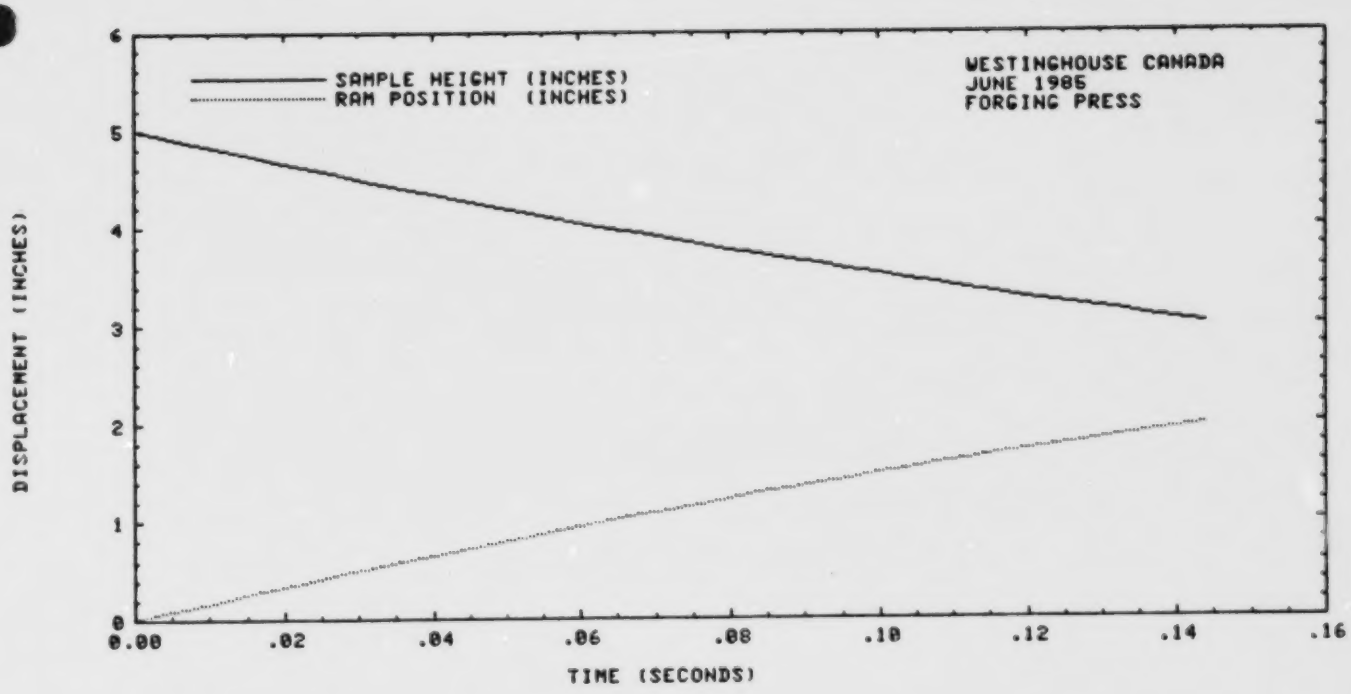


FIGURE 2

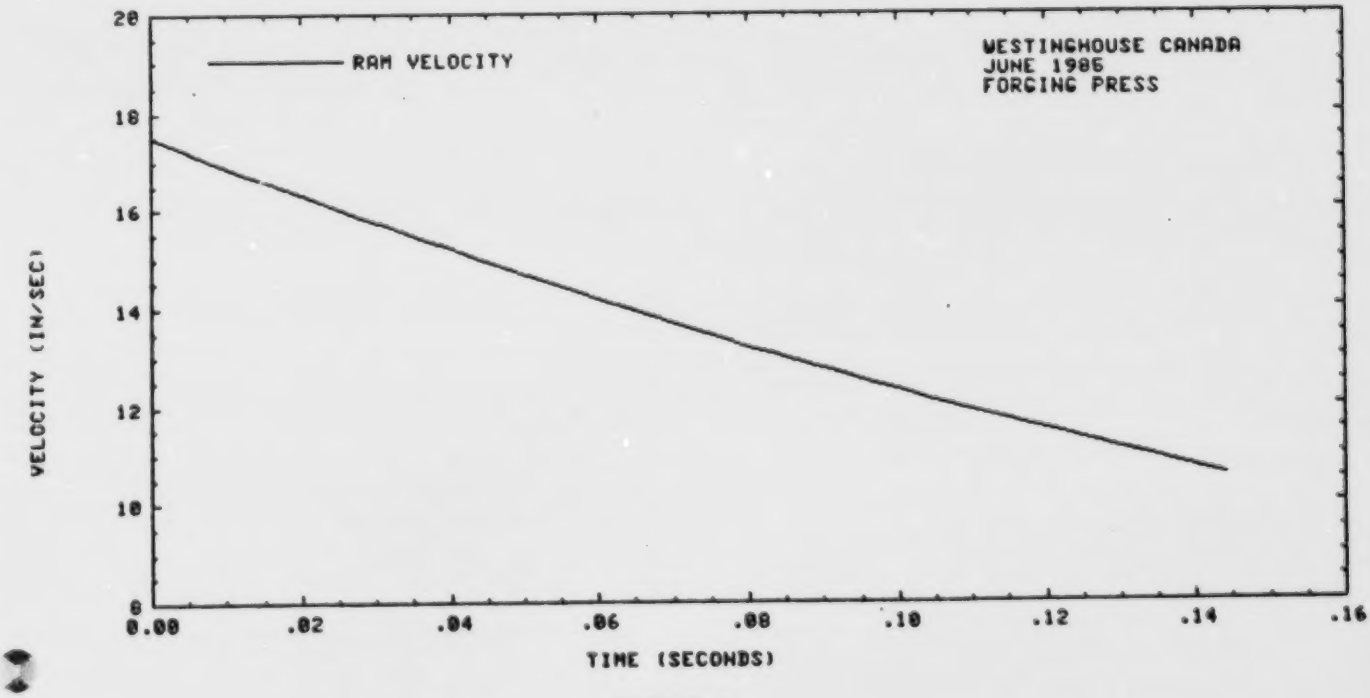


FIGURE 3

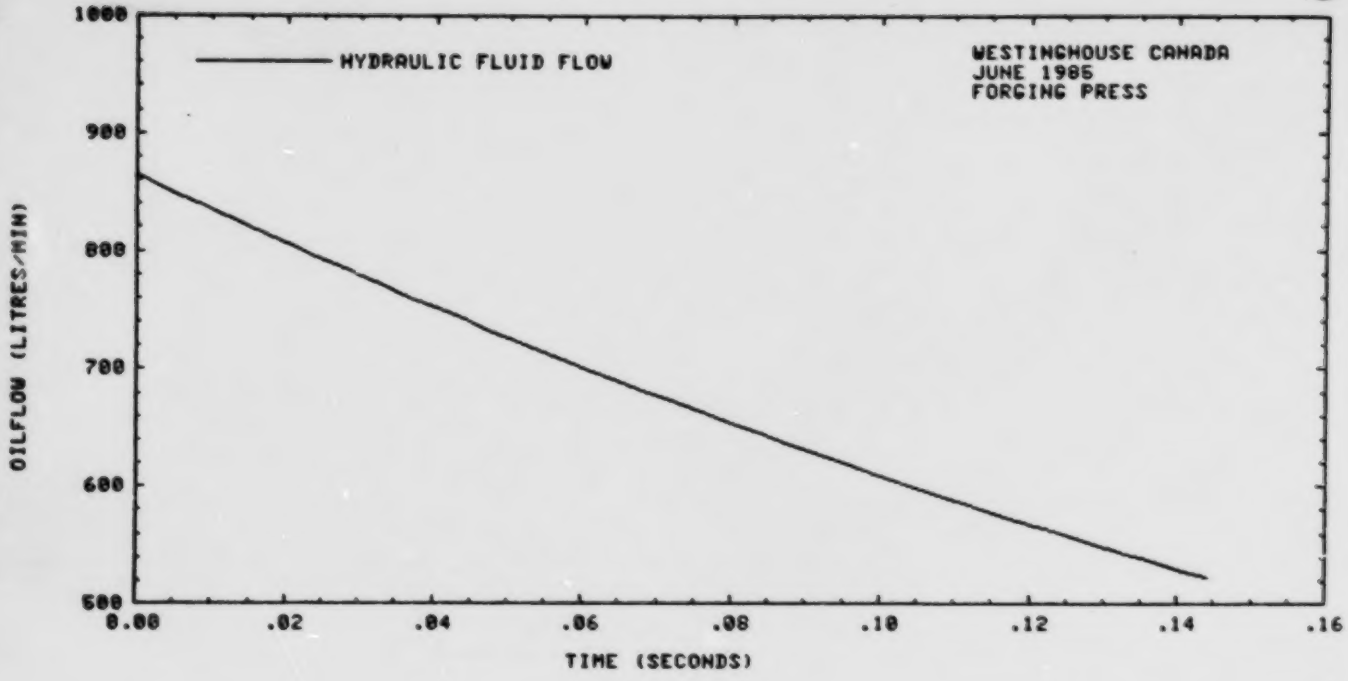


FIGURE 4

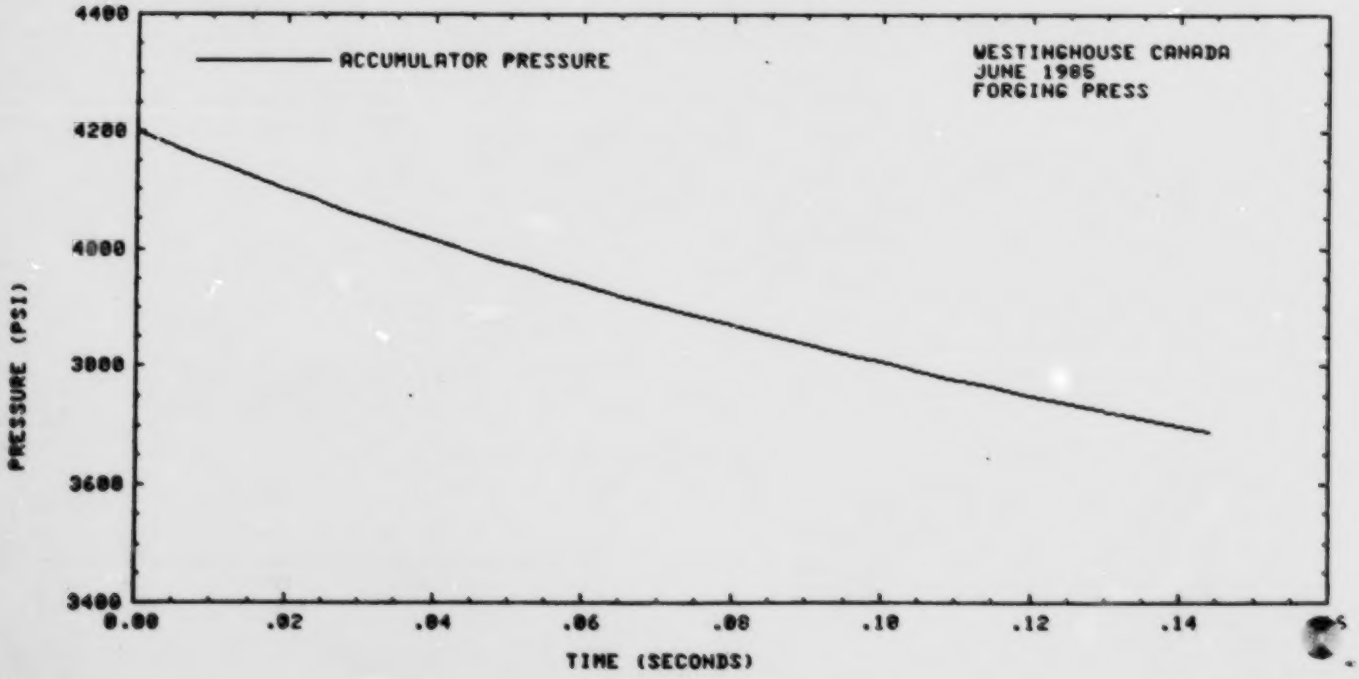


FIGURE 5

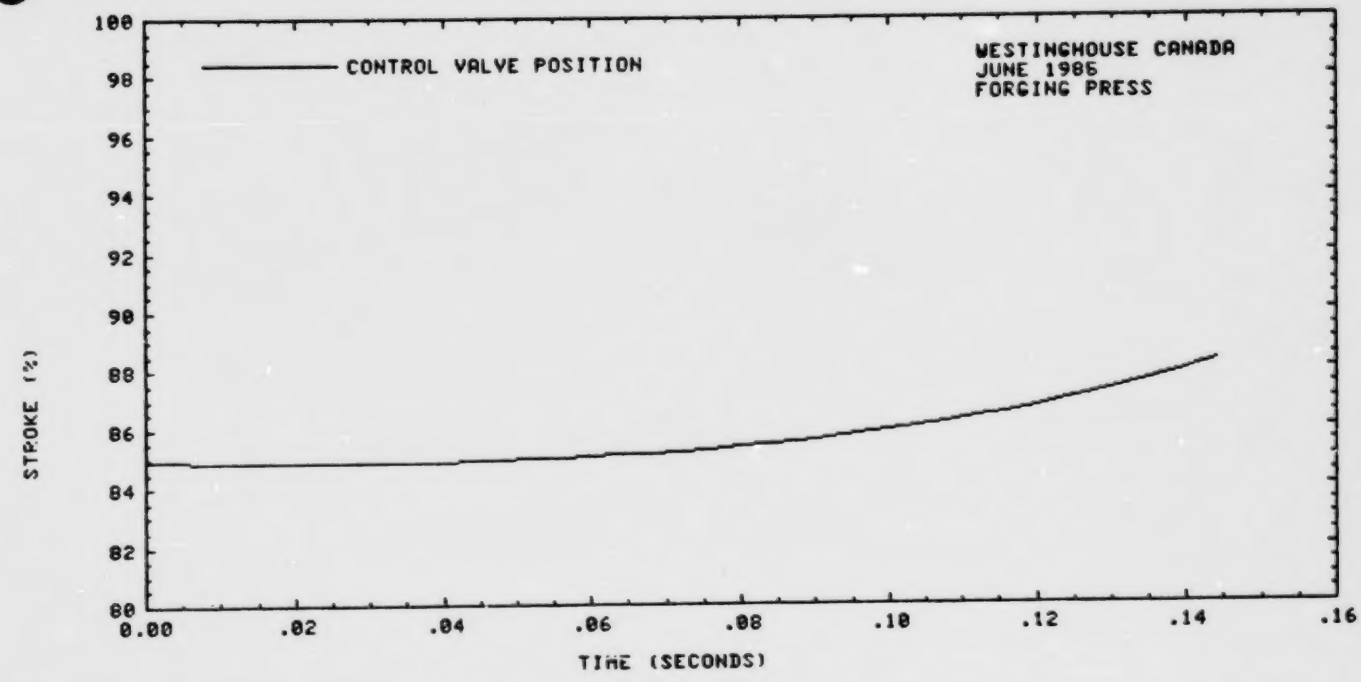


FIGURE 6

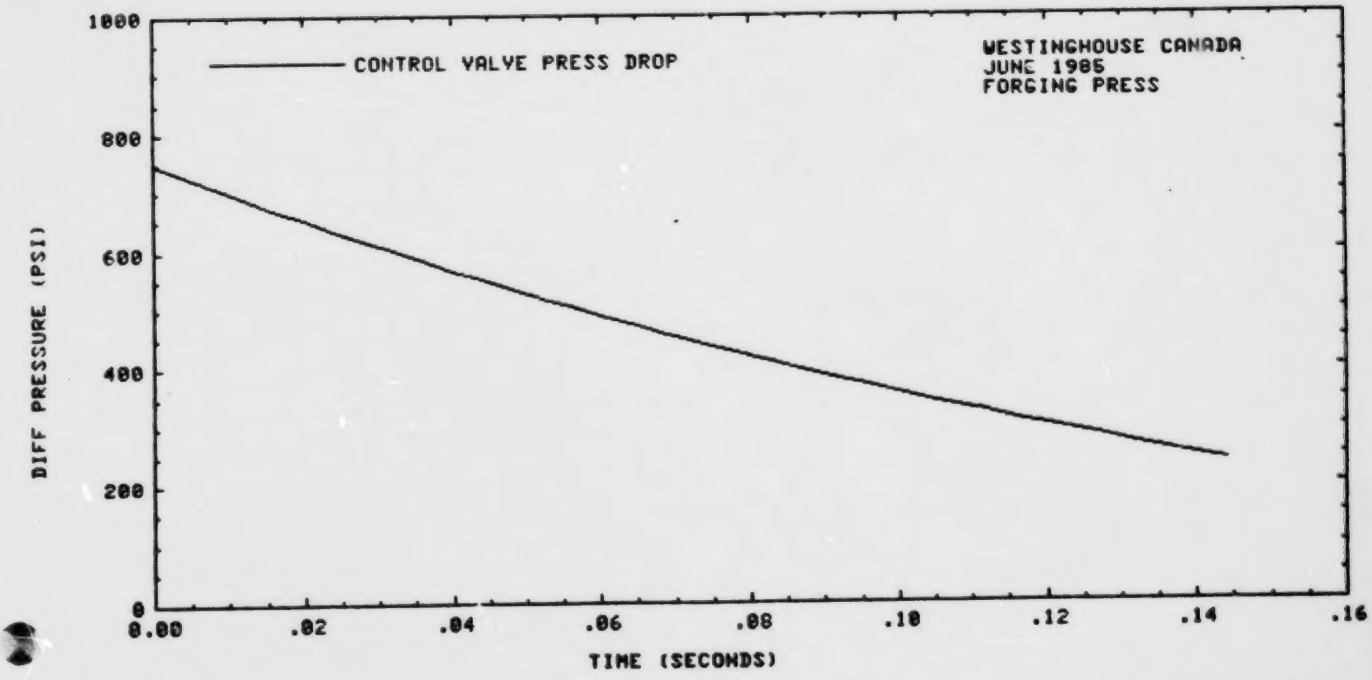


FIGURE 7

APPENDIX I: PROGRAM LISTING

```
2 *                 11:52 AM  THU., 13  JUNE, 1985
3       PROGRAM SUPER (4, 95),    FBR  (850618.0956)
4 *
5 *         Hydrualic Press Supervisor Program
6 *
7 *         Written by F.B. Russell  Westinghouse Canada
8 *
9 *         FORTRAN 77 used - however note some of the coding
10 *        is unique to HP equipment - particularly screen
11 *        controls (home cursor, line feed, clear display),
12 *        disk file I/O, terminal I/O, system clocks, etc.
13 *
14 *
15 *        Philosophy
16 *        ----------
17 *
18 *        Disk file header record contains all information needed
19 *        to run a session, i.e. operator name, test date, deformation
20 *        rate, profile correction factors, etc..   Any number of these
21 *        files would exist on disk including for example, the previous
22 *        run, or any number of typical runs.
23 *
24 *        Disk file once read into program will be keep in a common block
25 *        so it will be available to all subroutines.
26 *
27 *        For debug and demonstration purposes, calls and returns from
28 *        Taurus modules will be simulated.
29 *
30      dimension idcb1(144),inam1(3),isize(2),jvalve(6),savestroke(1024)
31      integer   iyn(2)
32 *
33      common idate(8),itest(8),irtc(4),
34     *       ichid(16,100),a(100),b(100),c(100),icode(100),
35     *       iscanner(100),ident(180),
36     *       xsect,height,strainrate,deformmax,contolint,
37     *       startleadtime,endleadtime,
38     *       poppetkh1,poppetkh2,poppetkh3,
39     *       proporkl1,proporkl2,proporkl3,
40     *       yieldest,dppropvalve,dpaccumloss,dplineloss,
41     *       offset(100),diethresh,boltthresh,numvalve,ivalve(6),
42     *       dpnom,strinit,gasvol,ipad(77),
43     *       volts(100),data(100)
44 *
45      data  inam1,ibuf1,irec1/2H<H,2HDP,2H00,3328,1/,iyn/1hN,1hY/
46      data  ioptn,isc,icrn/1,1270,34/,isize/26,0/,itype/1/,jopt/1/
47      data  ivdt,isto,ihc,   icd,   isp,igt,iund,iff6,icr,iblnk,iup
48     *     / 1,2200B,15550B,15512B,40B,76B,137B, 14B,15B,2H  ,15501B/
49 *
50      dpminallow = 150.0
51      cntlvalcon = 0.608
52      conversion = 60.0 / 61.023          !  in3/sec to litre/min
53      pistonarea = 201.0
54 *
55 *
56      write (1,134)  ihc,icd                ! home cursor, clear disp
```

```
57        write (1,101)                          ! header
58        call exec (3,ivdt+isto,0)              ! terminal timeout infinite
59        read  (1,134)  iwait
60 *
61 *
62 *      -------------------------
63 *      Open Disk File For A,B,C's  -  if file does not exist create it
64 *      -------------------------
65 *
66      1 write (1,102)
67        write (1,103)       icrn
68        call iget (1,       icrn)
69        write (1,104)       inam1,icrn,inam1(1),inam1(2)
70        read  (1,134)       inam3
71        if (inam3.eq.2hex.or.inam3.eq.2hEX)  stop
72        if (inam3.ne.2h  ) inam1(3) = inam3
73      2 call open  (idcb1,ierr,inam1,ioptn,isc,icrn)
74        if (ierr.lt.0) goto   3
75        call readf (idcb1,ierr,idate,ibuf1,ilen1,irec1)
76        if (ierr.LT.0) goto   3
77        write (1,105)     inam1,icrn,ilen1
78        call close (idcb1,ierr)
79        if (ierr.LT.0) goto 3
80        write (1,106)     inam1,icrn
81        goto 4
82 *
83      3 write (1,107)  ierr
84        if (ierr.ne.-6) goto 1
85        write (1,108)
86        read  (1,134) ians
87        if (ians.ne.2hY .and.ians.ne.2hy ) goto 1
88        call creat (idcb,ierr,inam1,isize,itype,isc,icrn)
89        if (ierr.ge.0) goto 2
90        write (1,107) ierr
91        goto 1
92 *
93 **      file open - now get current date, testname
94 *
95      4 write (1,109) itest, idate
96        call sytim  (2,irtc,idate)
97        write (1,110) idate,irtc
98        read  (1,134) iwait
99 *
100 *      -----------------
101 *      change test label
102 *      -----------------
103 *
104     20 if (jump.eq.1) write (1,302)
105        call tlabl (itest)
106        if (jump.eq.1) goto 300
107 *
108 *      ------------------------------------------
109 *      change data channel decriptions and constants
110 *      ------------------------------------------
111 *
```

```
112    30 if (jump.eq.1) write (1,303)
113       call cc    (100,a,b,c,ichid,icode,iscanner,idate,itest,irtc)
114       if (jump.eq.1) goto 300
115 *
116 *      ----------------------
117 *      change press parameters
118 *      ----------------------
119 *
120    40 if (jump.eq.1) write (1,304)
121       write (1,160) xsect
122       call  get  (1,xsect)
123       write (1,161) height
124       call  get  (1,height)
125    41 write (1,162) strainrate
126       call  get  (1,strainrate)
127       if (strainrate.lt.0.01.or.strainrate.gt.4.09) write (1,159)
128       if (strainrate.lt.0.01.or.strainrate.gt.4.09) goto 41
129       numvalves = 1
130       jvalve(1) = 1
131       if (strainrate.gt.0.25) jvalve(1) = 2
132       if (strainrate.gt.0.60) jvalve(1) = 3
133       if (strainrate.gt.1.00) numvalves = 2
134       if (strainrate.gt.1.00) jvalve(2) = 4
135       if (strainrate.gt.2.00) numvalves = 3
136       if (strainrate.gt.2.00) jvalve(3) = 5
137       if (strainrate.gt.3.00) numvalves = 4
138       if (strainrate.gt.3.00) jvalve(4) = 6
139    42 if (deformmax.gt.height) deformmax = .9 * height
140       write (1,163) deformmax
141       call  get  (1,deformmax)
142       if (deformmax.gt.height) write (1,157)
143       if (deformmax.gt.height) goto 42
144       event = - log ( (height - deformmax) / height ) / strainrate
145       write (1,156) numvalve ,(ivalve(k),k=1,numvalve )
146       write (1,155) numvalves,(jvalve(k),k=1,numvalves)
147       write (1,154)
148       read  (1,134) ians
149       if (ians.eq.2hN .or.ians.eq.2hn ) then
150          write (1,140) numvalve
151          call  iget (1,numvalve)
152          write (1,141) (ivalve(k),k=1,numvalve)
153          do 43 k = 1,numvalve
154          write (1,142) k,ivalve(k)
155    43    call  iget(1,ivalve(k))
156       else
157          numvalve = numvalves
158          do 44 k = 1,numvalve
159    44    ivalve(k) = jvalve(k)
160       endif
161       write (1,158) event
162       write (1,164) startleadtime
163       call  get  (1,startleadtime)
164       write (1,165) endleadtime
165       call  get  (1,endleadtime)
166       write (1,166) poppetkhl
```

```
      call  get  (1,poppetkh1)
      write (1,167) poppetkh2
      call  get  (1,poppetkh2)
      write (1,168) poppetkh3
      call  get  (1,poppetkh3)
      write (1,169) poppetkh1
      call  get  (1,poppetkh1)
      write (1,170) poppetkh2
      call  get  (1,poppetkh2)
      write (1,171) poppetkh3
      call  get  (1,poppetkh3)
      write (1,172) yieldest
      call  get  (1,yieldest)
      write (1,175) dplineloss
      call  get  (1,dplineloss)
      pressy = yieldest / pistonarea * xsect
      headavail = 4500.0 - pressy - dplineloss
      write (1,179) pressy,headavail
*     write (1,173) dppropvalve
*     call  get  (1,dppropvalve)
*     write (1,174) dpaccumloss
*     call  get  (1,dpaccumloss)
      write (1,176) diethresh
      call  get  (1,diethresh)
      write (1,177) boltthresh
      call  get  (1,boltthresh)
*
*     ---------------------
*     time step calculation
*     ---------------------
*
   50 if (jump.eq.1) write (1,305)
      if (event.le.2.048) timestep = 0.002
      if (event.le.2.048) numbstep = event / 0.002 + 1
      if (event.gt.2.048) timestep = ifix (event / 1.024 + 1.0) / 1000.
      if (event.gt.2.048) numbstep = event / timestep + 1
      write (1,178)   event,timestep,numbstep
      read  (1,134)   ians
      if (jump.eq.1) goto 300
*
*     ----------------------------
*     compute displacement profile
*     ----------------------------
*
   60 if (jump.eq.1) write (1,306)
      incr =  numbstep / 25
      write (1,190)
      ipause = 18
      loop = 0
   61 ilines = 1
      if (loop.eq.1) write (1,193)
      if (loop.eq.2) incr = 1
      if (loop.eq.2) ipause = numbstep + 1
      do 62 i = 1,numbstep,incr
      jtest = ilines / ipause * ipause - ilines
```

```
      if (jtest.eq.0) write (1,192)
      if (jtest.eq.0) read  (1,134) ians
      if (jtest.eq.0.and.loop.eq.0) write (1,190)
      if (jtest.eq.0.and.loop.eq.1) write (1,193)
      time = (i -1 ) * timestep
      samheight = height * exp (- strainrate * time)
      rampos    = height * (1.0 - exp (- strainrate * time))
      oilvol    = rampos * pistonarea    / 231.0            ! in us gals
      accumpr   = pressacc * gasvol / (gasvol + oilvol)
      if (jopt.eq.0) accumpr   = pressacc
      ramvel    = height * strainrate * exp (- strainrate * time)
      oilflow   = pistonarea * ramvel * conversion / numvalve
      if (loop.gt.0) dpcntlval= dpnom
      if (loop.gt.0.and.jopt.eq.1) dpcntlval= dpnom  -
     *                    (pressacc - accumpr)
      if (loop.gt.0.and.jopt.eq.1.and.dpcntlval.lt.0.0) write (1,145)
      if (loop.gt.0.and.jopt.eq.1.and.dpcntlval.lt.0.0) goto 63
      if (loop.gt.0) stroketh = 33. * oilflow /cntlvalcon
     .                   /sqrt(dpcntlval)
      if (loop.gt.0.and.stroketh.gt.100.0) write (1,189)
      if (loop.gt.0.and.stroketh.gt.100.0) goto 63
      if (loop.eq.0)
     *  write (1,191) i,time,samheight,rampos,ramvel,oilflow
      if (loop.eq.1)
     *  write (1,191) i,time,samheight,rampos,ramvel,oilflow,stroketh,
     *              accumpr,dpcntlval
      if (loop.eq.2) savestroke(i) = stroketh
   62 ilines = ilines + 1
   63 write (1,192)
      if (loop.eq.2) goto 211
      read  (1,134)  ians
      if (loop.eq.1) goto 65
*
***   Calculate minimum and maximum flow rates
*
      ramvel    = height * strainrate
      oilflowmax= pistonarea * ramvel * conversion / numvalve
      time = event
      ramvel    = height * strainrate * exp (- strainrate * time)
      oilflowmin= pistonarea * ramvel * conversion / numvalve
      write (1,198) oilflowmax,oilflowmin
      write (1,192)
      read  (1,134)  ians
*
***   Calculated corners of flow vs dp map
*
      str1 = 33.0 * oilflowmax / cntlvalcon / sqrt(dpminallow)
      str2 = 33.0 * oilflowmax / cntlvalcon / sqrt(dppropvalve)
      str3 = 33.0 * oilflowmin / cntlvalcon / sqrt(dpminallow)
      str4 = 33.0 * oilflowmin / cntlvalcon / sqrt(dppropvalve)
*     write (1,199) oilflowmax,str1,str2,oilflowmin,str3,str4,
*    *              dpminallow,dppropvalve
*     write (1,192)
*     read  (1,134) ians
      write (1,194) strinit
```

```
      call  get (1,strinit)
      if (strinit.gt.100.0) strinit = 100.0
      if (strinit.lt. 50.0) strinit =  50.0
      dpinit = (oilflowmax / cntlvalcon / (strinit-33.0)) ** 2
      if (dpinit.gt.headavail) write (1,195)
      if (dpnom.lt.dpinit) dpnom = dpinit
      if (dpnom.gt.headavail) dpnom = headavail
      write (1,197) dpinit,headavail,dpnom
      call get (1,dpnom)
      if (dpnom.lt.dpinit) dpnom = dpinit
      if (dpnom.gt.headavail) dpnom = headavail
      pressacc = pressy + dpnom + dplineloss
      write (1,196) pressacc
      read  (1,134) ians
      write (1,143) gasvol
      call  get (1,gasvol)
      if (jopt.ne.1) jopt = 0
      write (1,144)  iyn(jopt+1)
      read  (1,134) ians
      if (ians.eq.2hY .or.ians.eq.2hy ) jopt = 1
      if (ians.eq.2hN .or.ians.eq.2hn ) jopt = 0
      loop = 1
      goto 61
*
   65 if (jump.eq.1) goto 300
      goto 80
*
*     ---------------------
*     go / no go conditions
*     ---------------------
*
   70 if (jump.eq.1) write (1,307)
      nogo = iblnk                          ! TC2 channel 42
      call calc
      inogo = 0
      itc2 = 42
      if (data(itc2).gt.120.0) nogo = 2hNO
      if (data(itc2).gt.120.0) inogo = inogo + 1
      write (1,180) ichid(1,itc2),ichid(2,itc2),data(itc2),nogo
      read  (1,134) ians
*
      ipt6 = 11                             ! PT6 channel 11
      nogo = iblnk
      if (data(ipt6).gt.4500.0) nogo = 2hNO
      if (data(ipt6).gt.4500.0) inogo = inogo + 1
      write (1,181) ichid(1,ipt6),ichid(2,ipt6),data(ipt6),nogo
      read  (1,134) ians
*
*     ils2 = 35
*     nogo = iblnk
*     if (data(ils2).gt.0.5) nogo = 2hNO
*     if (data(ils2).gt.0.5) inogo = inogo + 1
*     write (1,182) (ichid(k,ils2),k=1,16),data(ils2),nogo
*     read  (1,134) ians
*
```

```
332 *     ils3 = 36
333 *     nogo = iblnk
334 *     if (data(ils3).gt.0.5) nogo = 2hNO
335 *     if (data(ils3).gt.0.5) inogo = inogo + 1
336 *     write (1,182) (ichid(k,ils3),k=1,16),data(ils3),nogo
337 *     read  (1,134) ians
338 *
339       do 72 ival = 51,65
340       nogo = iblnk
341       if (data(ival).gt.0.5) nogo = 2hNO
342       if (data(ival).gt.0.5) inogo = inogo + 1
343       write (1,182) (ichid(k,ival),k=1,16),data(ival),nogo
344    72 read  (1,134) ians
345 *
346       thresh = diethresh
347       do 76 ival = 12,16
348       if (ival.gt.13) thresh = boltthresh
349       nogo = iblnk
350       if (data(ival).gt.thresh) nogo = 2hNO
351       if (data(ival).gt.thresh) inogo = inogo + 1
352       write (1,182) (ichid(k,ival),k=1,16),data(ival),nogo
353    76 read  (1,134) ians
354 *
355       if (inogo.eq.0) write (1,186)
356       if (inogo.gt.0) write (1,187) inogo
357       read (1,134) ians
358 *
359    73 write (1,183)
360       do 74 ipt = 1,11
361       if (ipt.eq.5) goto 74
362       write (1,184) ipt,(ichid(k,ipt),k=1,16),offset(ipt),data(ipt)
363    74 continue
364       write (1,185)
365       read  (1,134) ians
366       if (ians.ne.2hY .and.ians.ne.2hy ) goto 75
367       call vofst
368       call calc
369       goto 73
370 *
371    75 continue
372 *
373       if (mini.eq.3.and.inogo.eq.0) goto 210       ! alarms clear - proceed
374       if (mini.eq.3.and.inogo.gt.0) goto 200       ! resolve alarms
375       if (jump.eq.1) goto 300
376 *
377 *      ---------------
378 *      offset voltages
379 *      ---------------
380 *
381    80 if (jump.eq.1) write (1,308)
382       call vofst
383       if (jump.eq.1) goto 300
384 *
385 *      -------------------------
386 *      change sample description
```

```
387 *      -------------------------
388 *
389    90 if (jump.eq.1) write (1,309)
390       call cmnts (ident)
391       if (jump.eq.1) goto 300
392 *
393 *      ---------
394 *      main menu
395 *      ---------
396 *
397   300 jump = 1
398       menu = 0
399       WRITE (1,151)
400       CALL  IGET (1,MENU)
401       if (menu.lt.1)  goto 300
402       if (menu.gt.11) goto 300
403       write (1,134) ihc,icd
404       goto (  1, 20, 30, 40, 50, 60, 70, 80, 90, 91,200), menu
405 *
406 *      ------------------------
407 *      mini menu - sample data
408 *      ------------------------
409 *
410   200 write (1,134) ihc,icd
411       call exec (3,ivdt+isto,500)          !  terminal timeout 5 sec
412   201 mini = 0
413       call sampl (1,1)
414       write (1,153) ihc,ihc,igt,iund
415       call iget (1, mini)
416       if (mini.le.0) goto 201
417       if (mini.eq.2) call sampl (6,1)
418       if (mini.eq.2) goto 201
419       if (mini.ge.4) goto 201
420       write (1,134) ihc,icd
421       call exec (3,ivdt+isto,30000)
422       if (mini.eq.3) goto 70
423       goto 300
424 *
425 *      -------------------------
426 *      start download proceedure
427 *      -------------------------
428 *
429   210 write (1,400)                                  !  download constants
430       loop = 2
431       goto 61
432   211 write (1,410)
433       do 212 i = 1,numbstep                          !  download stroke
434   212 write (1,411) i,savestroke(i),iup
435       write (1,411) numbstep,savestroke(numbstep),icr
436       write (1,412)
437       read  (1,134) ians
438       if (ians.ne.2hgo.and.ians.ne.2hGO) write (1,414)
439       if (ians.ne.2hgo.and.ians.ne.2hGO) call iget (1,ians)
440       if (ians.ne.2hgo.and.ians.ne.2hGO) goto 200
441       write (1,413)                                  !  start Taurus
```

```
      write (1,192)
      call iget (1,ians)
      goto 200
  400 format ("TAURUS: number of valves, valve numbers,feedback ",
     *        "constants")
*
*      ----------------------------
*      rewrite revised header record   then exit program
*      ----------------------------
*
   91 call exec (3,ivdt+isto,30000)
      write (1,113)
      read  (1,134) ians
      if (ians.ne.2hN .and.ians.ne.2hn ) goto 93
   92 write (1,103)      icrn
      call iget (1,      icrn)
      inam1(3) =  inam1(3) + 1
      write (1,104)      inam1,icrn,inam1(1),inam1(2)
      read  (1,134)      inam3
      if (inam3.eq.2hex.or.inam3.eq.2hEX)  goto 92
      if (inam3.ne.2h  ) inam1(3) = inam3
      call creat (idcb,ierr,inam1,isize,itype,isc,icrn)
      if (ierr.ge.0) goto 93
      write (1,107) ierr
      goto 92
   93 call open  (idcb1,ierr,inam1,ioptn,isc,icrn)
      if (ierr.lt.0) goto   94
      call writf (idcb1,ierr,idate,ibuf1)
      if (ierr.LT.0) goto   94
      write (1,112)     inam1,icrn,ibuf1
      call close (idcb1,ierr)
      goto 99
*
***    error handling on disk file rewrite
*
   94 write (1,111) ierr
      goto 99
*
***         all formats follow
*
  101 format (" H Y D R A U L I C   P R E S S   S U P E R V I S O R",
     .  //,  "          Hit return to continue  >_")
  102 format ( /" File for A,B,C's, offsets, etc",/)
  103 format ( /" Disk cartridge number  [",I2,"] ... _")
  104 format ( /" File name - "2A2"["1A2"]:Sc:"I2" or [EX]it",
     .          /" Change      "2A2"_")
  105 format ( /" File "3A2"::"I2"::"I5" - open")
  106 format ( /" File "3A2"::"I2" - closed")
  107 format ( /" File manager error:"I6)
  108 format ( /" File does not exist. Enter Y to create it   _")
  109 fcrmat (//" Disk file test: ",8A2," Ran: ",8A2)
  110 format ( /" Today is: ",8A2," Time is now: "I2":"I2":",
     *       I2"."I2"  ... _")
  111 format ( /" File manager error:"I6," detected on file rewrite")
  112 format ( /" File "3A2"::"I2"::"I5" - written and closed")
```

```
497   113 format ( /"  Store current information on original file ",
498      .             "[Y/N] ... Y_")
499   134 format (10a2)
500   140 format (/"  Enter number of valves ["i1"] ... _")
501   141 format ( "  Valves no.s "5(i2,", "),i2)
502   142 format ( "  Valves no "i2," now",i2," ... _")
503   143 format (/"  Enter gas volume in accumulator (us gal) ["f4.2,
504      .          "] ... _")
505   144 format (/"  Will the accumulator be isolated [Y/N] ... "a1"_")
506   145 format (/"  WARNING!  Accumulator pressure has dropped  ",/,
507      .         "  too low to yield sample ")
508   151 FORMAT (2/,20x,17("$"),/,20x,"$$$ MAIN MENU $$$",/
509      .           ,20x,17("$"),//
510      .  "   1. Open Disk File            7.  Alarm Conditions"/,
511      .  "   2. Test label                8.  Offset voltages"/,
512      .  "   3. Channel assignments       9.  Test description "/,
513      .  "   4. Press control parameters  10. END PROGRAM"/,
514      .  "   5. Rates and periods         11. Scan Data - MINI MENU",/,
515      .  "   6. Calculate displacement     ",//
516      .  "          Enter option ... _")
517   153 FORMAT (A2,13X,
518      .     "HYDRAULIC PRESS CONTROL - MINI MENU",
519      . /,15X,"Exit   Print    Initiate Control",
520      . /,15X," 1      2           3   ",/,3A2)
521   154 format (/,"  Use suggested valves    [Y/N] ... Y_")
522   155 format (/,3X,I3," valves must be used; suggest no.s "3(i2", "),i2)
523   156 format (/,3X,I3," valves now selected; No.s "5(i2,", "),i2)
524   157 format (/"  Maximum deformation should not exceed height",/)
525   158 format (/"    Event expected to last "f6.4" seconds")
526   159 format (/"  Please keep strain rate between 0.01 and 4.09",/)
527   160 format (/"  Sample cross section area (in2)    ["f6.5"] ... _")
528   161 format ( "  Sample height              (in)     ["f6.5"] ... _")
529   162 format ( "  Nominal strain rate        (sec-1)  ["f6.5"] ... _")
530   163 format ( "  Maximum deformation        (in)     ["f6.5"] ... _")
531   164 format (/"  Start lead time            (sec)    ["f6.5"] ... _")
532   165 format ( "  End   lead time            (sec)    ["f6.5"] ... _")
533   166 format (/"  Feedback error factor Kh1           ["f6.5"] ... _")
534   167 format ( "  Feedback error factor Kh2           ["f6.5"] ... _")
535   168 format ( "  Feedback error factor Kh3           ["f6.5"] ... _")
536   169 format (/"  Feedback error factor K11           ["f6.5"] ... _")
537   170 format ( "  Feedback error factor K12           ["f6.5"] ... _")
538   171 format ( "  Feedback error factor K13           ["f6.5"] ... _")
539   172 format (/"  Yield strength estimate   (psi)     ["f6.5"] ... _")
540   173 format ( "  Max proportional valve DP (psi)     ["f6.5"] ... _")
541   174 format ( "  Accumulator pressure loss (psi)     ["f6.5"] ... _")
542   175 format ( "  Line loss estimate        (psi)     ["f6.5"] ... _")
543   176 format (/"  Die  strain threshold     (uin/in)  ["f6.5"] ... _")
544   177 format ( "  Bolt strain threshold     (uin/in)  ["f6.5"] ... _")
545   178 format (/"  Control loop overall time:   "f6.5" seconds",/,
546      .         "  Cycle time / scan rate   :   "f6.5" seconds",/,
547      .         "  Number of time steps     :   "f6.5"   ... >_")
548   179 format (/5x,f5.1," psi required to yield specimen estimated",/,
549      .         5x,f5.1," psi head available to drive ram"/)
550   180 format (/2x,2A2"upper limit  120 F   "
551      .  6x,"- now "f6.2" : condition is",1x,A2," GO ... >_")
```

```
552   181 format ( 2x,2A2"upper limit 4500 psi ",
553      .  6x,"- now "f6.2" : condition is",1x,A2," GO ... )_")
554   182 format (2x,16a2," now "f6.2" : condition is ",A2," GO ... )_")
555   183 format (/"  Offset voltage confirmation",//,
556      *         "  Ch  Description",22x,"Offset   Value",/)
557   184 format (i4,1x,16A2,2x,f6.5,2x,f6.5)
558   185 format (/"  Want to revise these offsets ? [Y/N] ... N_")
559   186 format (/,"  All alarm conditions cleared for event     )_")
560   187 format (/2x,I3," alarm conditions must be resolved !!   )_")
561   189 format (/"  WARNING! Control valve stroke exceeds 100% ",/,
562      .         "  Lower initial stroke, or increase initial DP"/)
563   190 format ("  Oil Flow Requirements",//,
564      . "Step   Time   Smpl Hght   Ram Pos   Ram Vel   Oil Flow"/,
565      . "  #     sec     inches      inches    in/sec     L/min "/)
566   191 format (1x,i3,2x,f6.4,4x,f6.4,5x,f6.4,4x,f6.4,4x,f6.1,4x,f6.3,
567      .        3x,f5.1,3x,f5.1)
568   192 format (/" ... )_")
569   193 format ("  Oil Flow Requirements and Depressurization",
570      *   " Predictions",//
571      . "Step   Time   Smpl Hght   Ram Pos   Ram Vel   Oil Flow",
572      . "  Stroke  Acc Prss  DPval",/,
573      . "  #     sec     inches      inches    in/sec     L/min ",
574      . "     %        psi     psi"/)
575   194 format (/"  Initial stroke position ["f5.2"] ... _")
576   195 format (/"  WARNING! Control valve pressure drop exceeds ",
577      .          "available head",/)
578   196 format (/"  Set accumulator pressure to "f5.1" psi     _")
579   197 format (/"  Initial control valve pressure drop must be",/,
580      .         "  greater than "f5.1" but less than "f5.1" psi.",//,
581      .         "  Enter initial value ... ["f5.1"] ... _")
582   198 format (/"  Maximum oil flow required is "f5.1" litres/min",/,
583      .         "  Minimum oil flow required is "f5.1" litres/min",/)
584   199 format (/"   flow                 required stroke  ",//,
585      .         " max= "f5.1,10x,f5.2,10x,f5.2,//,
586      .         " min= "f5.1,10x,f5.2,10x,f5.2,//,
587      .         " control valve  DP   ",f5.2,10x,f5.2,"  psi"/)
588   302 format ("  Test Label",/)
589   303 format ("  Channel Assignments",/)
590   304 format ("  Press Control Parameters",/)
591   305 format ("  Time step Calculation",/)
592   306 format ("  Displacement & stroke calculation",/)
593   307 format ("  Alarm Conditions",/)
594   308 format ("  Offset Voltages",/)
595   309 format ("  Test Description",/)
596   410 format (//"TAURUS download stroke starting",//)
597   411 format ("TAURUS download stroke: "i4,2x,f6.3,A2)
598   412 format (/"TAURUS download complete, enter [GO] to initiate press"
599      *         "  ... _")
600   413 format (/"TAURUS started!",/)
601   414 format (/"TAURUS run aborted     _")
602    99 end
```

```
Module SUPER          No errors     Prog:  0083    Blank Common: 3328
FTN7X 2326/838607     No warnings   Save:  None    Local Eqa:    None
```

```
603 *
604       SUBROUTINE SYTIM (I,IRTC,IDATE), FBR      830721.1212
605 *
606 *      -------------------------------
607 *      Date and time from system clock
608 *      -------------------------------
609 *
610       DIMENSION IRTC(4),IDATE(8),ITIM(5),IDAT(15)
611       CALL EXEC  (11,ITIM)
612       IRTC(1) = ITIM(4)
613       IRTC(2) = ITIM(3)
614       IRTC(3) = ITIM(2)
615       IRTC(4) = ITIM(1)
616       IF (I.NE.2) RETURN
617       CALL FTIME  (IDAT)
618       IDATE(1) = IDAT(14)
619       IDATE(2) = IDAT(15)
620       IDATE(3) = IDAT(10)
621       IDATE(4) = IDAT(11)
622       IDATE(5) = IDAT(12)
623       IDATE(6) = 2H
624       IDATE(7) = IDAT(9)
625       IDATE(8) = 2H
626       RETURN
627       END
```

Module SYTIM No errors Prog: 102 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Ema: None

```
628 *
629 *                  10:12 AM  FRI.,  7  DEC., 1984
630       SUBROUTINE TLABL (ITEST), FBR      <850618.0956>
631 *
632 *      -------------------------
633 *      Line editor for test label
634 *      -------------------------
635 *
636       DIMENSION ITEST(8),LTEST(8),IREG(2)
637       EQUIVALENCE (REG,IREG,IA),(IREG(2),IB)
638       DATA IBLNK/2H  /,IVDT/1/
639 *
640       ITRUN = 0
641       WRITE (1,101)
642       DO 34 LL=1,8
643    34 LTEST(LL) = IBLNK
644       WRITE (1,102) (ITEST(K),K=1,8)
645       REG = EXEC (1,IVDT+400B,LTEST,-16)
646       IF (IB.EQ.0) GOTO 37
647 *
648       IB2 = (IB+1) / 2
649       IF (IB2.GT.8)  IB2 = 8
650       DO 55 I = 1,IB2
651       IR1= IAND(LTEST(I),   377B)
652       IRR= IAND(ITEST(I),   377B)
653       IL = IAND(LTEST(I),177400B)
654       ILL= IAND(ITEST(I),177400B)
655       IF (I.EQ.IB2.AND.IB2*2.NE.IB) IR1= IRR
656       IF (IR1.NE.57B)    IRR = IR1
657       IF (IL.NE.27400B)  ILL = IL
658       IF (IL.EQ.20400B.OR.IR1.EQ.41B) ITRUN = 1
659       IF (IL.EQ.20400B)  ILL = 20000B
660       IF (IL.EQ.20400B)  IRR =    40B
661       IF (IR1.EQ.00041B) IRR =    40B
662       ITEST(I) = ILL + IRR
663       I1 = I + 1
664       IF (ITRUN.EQ.1) GOTO 56
665    55 CONTINUE
666       GOTO 37
667    56 DO 57 K = I1,8
668    57 ITEST(K) = IBLNK
669    37 WRITE (1,103) ITEST
670       READ  (1,104) IWAIT
671       RETURN
672   101 FORMAT ( /"  Edit Test Label (cr nc; / nc; ! truncate)",/)
673   102 FORMAT (2x,"",8A2,"",/,") _")
674   103 FORMAT ("",2x,"",8A2,"","  )_")
675   104 FORMAT (a2)
676       END

Module TLABL          No errors     Prog:   326    Blank Common: None
FTN7X 2326/830607     No warnings   Save:  None    Local Eqa:    None
```

```
677 *
678       SUBROUTINE  CC (ISIZ,A,B,C,ICHID,ICODE,ISCANNER,IDATE,ITEST,IRTC)
679      *      , FBR      <850618.0956>
680 *
681 *    MAKE ONLINE REDUCTION CONSTANT CHANGES
682 *
683       DIMENSION A(ISIZ),B(ISIZ),C(ISIZ),ICHID(16,ISIZ),IDUMY(16),
684      .   IDATE(8),ITEST(8),IRTC(4),IREG(2),ICODE(ISIZ),ISCANNER(ISIZ)
685       INTEGER S,ITTY(2)
686       EQUIVALENCE (REG,IREG),(IA,IREG(1)),(IB,IREG(2))
687       DATA IBLNK/2H  /
688 *
689 *      Number of constant changes
690 *
691       JST   = 1
692       JEND  = ISIZ
693     1 WRITE(1,101)
694       NCHNG = 0
695       call iget (1, NCHNG)
696       IF(NCHNG) 1,10,2
697 *
698 *      Initially give copy of constants on terminal
699 *
700     2 WRITE (1,111) JST,JEND
701       call  iget (2,JST,JEND)
702       IF (JST .LT.  1)   JST=1
703       IF (JEND.GT.ISIZ)   JEND=ISIZ
704       DO 3 K=JST,JEND,50
705       WRITE (1,99) IDATE,ITEST,IRTC
706       IEND = K + 49
707       IF (IEND.GT.JEND) IEND = JEND
708     3 WRITE (1,100)(J,(ICHID(I,J),I=1,16),A(J),B(J),C(J),
709      .                ISCANNER(J),ICODE(J),J=K,IEND)
710       M = JST - 1
711 *
712 *      DO NCHNG CHANGES
713 *
714       WRITE (1,133)
715       DO 6 I=1,NCHNG
716       M = M + 1
717       WRITE(1,102) I , M
718       call iget (1,m)
719       IF (M.LE.0.OR.M.GT.ISIZ) WRITE (1,999)
720       IF (M.LE.0.OR.M.GT.ISIZ) GOTO 6
721       WRITE (1,105) M,A(M),B(M),C(M)
722       CALL  GET (3,   A(M),B(M),C(M) )
723       write (1,112) m,iscanner(m),icode(m)
724       call  iget(2, iscanner(m),icode(m))
725       ITRUN = 0
726       DO 5 KK=1,16
727     5 IDUMY(KK) = IBLNK
728       WRITE (1,106) M, (ICHID(KK,M),KK=1,16)
729       REG = EXEC (1,1+400B,IDUMY,-32)
730       IF (IB.EQ.0) GOTO 58
731       IB2 = (IB+1) / 2
```

```
      IF (IB2.GT.16)  IB2 = 16
      DO 55 L = 1,IB2
      IR1= IAND(IDUMY(L),  377B)
      IRR= IAND(ICHID(L,M),377B)
      IL = IAND(IDUMY(L),  177400B)
      ILL= IAND(ICHID(L,M),177400B)
      IF (L.EQ.IB2.AND.IB2*2.NE.IB) IR1= IRR
      IF (IR1.NE.57B)   IRR = IR1
      IF (IL.NE.27400B) ILL = IL
      IF (IL.EQ.20400B.OR.IR1.EQ.41B) ITRUN = 1
      IF (IL.EQ.20400B) ILL = 20000B
      IF (IR1.EQ.00041B) IRR =    40B
      ICHID(L,M) = ILL + IRR
      IF (ITRUN.EQ.1) GOTO 56
   55 CONTINUE
   56 IF (ITRUN.NE.1) GOTO 58
      DO 57 N = L,16
   57 ICHID(N,M) = 20040B
   58 WRITE (1,110)
      WRITE (1,116) M, (ICHID(KK,M),KK=1,16),A(M),B(M),C(M),
     .            ISCANNER(M),Icode(M)
    6 IF (M.LT.1) WRITE (1,110)
*
*     Print hard copy if desired
*
    7 WRITE(1,103)
      READ(1,107) ITTY
      IF (ITTY.NE.2Hy .AND.ITTY.NE.2HY ) GOTO 9
      DO 33 K=1,ISIZ,50
      WRITE (6,99) IDATE,ITEST,IRTC
      IEND = K + 49
      IF (IEND.GT.ISIZ) IEND = ISIZ
      WRITE (6,100)(J,(ICHID(I,J),I=1,16),A(J),B(J),C(J),
     .            ISCANNER(J),ICODE(J),J=K,IEND)
   33 WRITE (6,108)
*
*     see if any more changes desired
*
    9 WRITE (1,104)
      READ  (1,107) ITTY
      IF (ITTY.EQ.2Hn .OR.ITTY.EQ.2HN ) GOTO 1
   10 RETURN
*
*  FORMATS FOLLOW
*
   99 FORMAT (/10X"D A T A    A C Q U I S I T I O N ",
     *         "   C O N S T A N T S"
     .       2/" DATE: "8A2"   TEST: "8A2"      TIME: "3(I2":")I2)
  100 FORMAT (/"  CH   FUNCTION"28X"A"8X"B"9X"C       SCNR  CHAN"//
     .       50(1X,I3,1X,16A2,2X,F8.6,2X,F8.6,2X,F8.6,4X,I2,4X,I2/))
  101 FORMAT ( /"  Number of constant changes ... _")
  102 FORMAT ( /"  Change #"I3,
     .         /"  Channel # ... ["I3"] ... _")
  103 FORMAT ( /"  Hard copy of new constants [Y/N] N_")
  104 FORMAT ( /"  Constants correct ? [Y/N] Y_")
```

```
787   105 FORMAT ( "                                    A        B         C"
788      .         /"  Reduction constants ("I3") "
789      .       F8.6,2X,F8.6,2X,F9.7,/,30X,"_")
790   112 FORMAT ( "                                     Scanner   Channel"
791      .         /"  Control constants   ("I3") "
792      .       6X,I2,6X,I2,/,35X,"_")
793   106 FORMAT ( "
                     Description         ("I3") "16A2
794      .          "
795   107 FORMAT (16A2)
796   108 FORMAT ("1")
797   110 FORMAT ( "_")
798   111 FORMAT ( /"  First and last display channels = ",2I4," ... _")
799   116 FORMAT ( " Ch ("I3") "16A2,
800      .          2X,F8.6,2X,F8.6,2X,F8.6,2x,I2,2x,I2/)
801   133 FORMAT ( /"  Line editor available for descriptions",/)
802   999 FORMAT ( "  Sorry, ch #  is out of range",///)
803       END
```

Module CC No errors Prog: 1369 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Eqa: None

```
804 *
805 *                    1:44 PM  WED., 20  MAR., 1985
806       SUBROUTINE GET (N,V1,V2,V3,V4,V5),  FBR
807       DIMENSION IBUF(40),IREG(2),VAL(5)
808       EQUIVALENCE (IREG,IA,REG),(IREG(2),IB)
809       VAL(1) = V1
810       IF (N.GT.1) VAL(2) = V2
811       IF (N.GT.2) VAL(3) = V3
812       IF (N.GT.3) VAL(4) = V4
813       IF (N.GT.4) VAL(5) = V5
814 *
815     1 REG = EXEC (1,401B,IBUF,40)
816       IF    (IB.EQ.0)              GOTO 3
817       IF    (IBUF(1).EQ.2H/ )      GOTO 3
818       IB1 = IB + 1
819       IBUF(IB1) = 2H /
820       DECODE  (80,*,IBUF,!OSTAT=IOS,ERR=4) (VAL(K),K=1,N)
821       IF (N.GT.4) V5 = VAL(5)
822       IF (N.GT.3) V4 = VAL(4)
823       IF (N.GT.2) V3 = VAL(3)
824       IF (N.GT.1) V2 = VAL(2)
825       V1 = VAL(1)
826     3 RETURN
827 *
828 ***   error condition
829 *
830     4 WRITE (1,100) IOS
831       GOTO 1
832   100 FORMAT ("## Error "I6" detected.  Please re-enter _")
833       END
```

Module GET No errors Prog: 247 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Ema: None

```
834 *
835 *     Integer version
836 *
837       SUBROUTINE IGET (N,IV1,IV2,IV3,IV4,IV5),  FBR
838       DIMENSION IBUF(40),IREG(2),IVAL(5)
839       EQUIVALENCE (IREG,IA,REG),(IREG(2),IB)
840 *
841       IVAL(1) = IV1
842       IF (N.GT.1) IVAL(2) = IV2
843       IF (N.GT.2) IVAL(3) = IV3
844       IF (N.GT.3) IVAL(4) = IV4
845       IF (N.GT.4) IVAL(5) = IV5
846     1 REG = EXEC (1,401B,IBUF,40)
847       IF    (IB.EQ.0)              GOTO 3
848       IF    (IBUF(1).EQ.2H/ )      GOTO 3
849       IBUF(IB+1) = 2H /
850       DECODE  (80,*,IBUF,IOSTAT=IOS,ERR=4) (IVAL(K),K=1,N)
851       IF (N.GT.4) IV5 = IVAL(5)
852       IF (N.GT.3) IV4 = IVAL(4)
853       IF (N.GT.2) IV3 = IVAL(3)
854       IF (N.GT.1) IV2 = IVAL(2)
855       IV1 = IVAL(1)
856     3 RETURN
857 *
858 ***   error condition
859 *
860     4 WRITE (1,100) IOS
861       GOTO 1
862   100 FORMAT ("## Error "I6" detected.  Please re-enter _")
863       END
```

```
Module IGET             No errors     Prog:   218    Blank Common: None
FTN7X  2326/830607      No warnings   Save:  None    Local Equ:    None
```

```
864 *
865 *
866 *                  10:12 AM  FRI.,  7  DEC., 1984
867       SUBROUTINE CMNTS (ICMTS,MINI), FBR      (850618.0956)
868 *
869 *      ------------------------------------------
870 *      This subroutine allows changes to comments
871 *      ------------------------------------------
872 *
873       DIMENSION ICMTS(180),JCMTS(36),IREG(2)
874       EQUIVALENCE (REG,IREG,IA),(IREG(2),IB)
875       DATA IBLNK/2H  /,IVDT/1/,IHC,ICD/15550B,15512B/
876 *
877       WRITE (1,118)     ICMTS
878       DO 31 J = 1,5
879       ITRUN = 0
880       DO 34 LL=1,36
881    34 JCMTS(LL) = IBLNK
882       JOF = (J-1) * 36
883       WRITE (1,198) (ICMTS(JOF+K),K=1,36)
884       REG = EXEC (1,IVDT+400B,JCMTS,-72)
885       IF (IB.EQ.0) GOTO 31
886 *
887       IB2 = (IB+1) / 2
888       IF (IB2.GT.36)  IB2 = 36
889       DO 55 I = 1,IB2
890       N36 = (J-1) * 36 + I
891       IR1= IAND(JCMTS(I),  377B)
892       IRR= IAND(ICMTS(N36),377B)
893       IL = IAND(JCMTS(I),  177400B)
894       ILL= IAND(ICMTS(N36),177400B)
895       IF (I.EQ.IB2.AND.IB2*2.NE.IB) IR1= IRR
896       IF (IR1.NE.57B)   IRR = IR1
897       IF (IL.NE.27400B) ILL = IL
898       IF (IL.EQ.20400B.OR.IR1.EQ.41B) ITRUN = 1
899       IF (IL.EQ.20400B) ILL = 20000B
900       IF (IR1.EQ.00041B) IRR =    40B
901       ICMTS(N36) = ILL + IRR
902       IF (ITRUN.EQ.1) GOTO 56
903    55 CONTINUE
904    56 IF (ITRUN.NE.1) GOTO 31
905       DO 57 K = 1,36
906       N36 = (J-1) * 36 + K
907    57 ICMTS(N36) = 0
908    31 CONTINUE
909       WRITE (1,197) ICD,ICMTS
910       IF (MINI.EQ.0) GOTO 37
911       WRITE (1,152) IHC,ICD
912    37 RETURN
913   118 FORMAT ( /5X"Sample Description"2/5(2X,""36A2"",/),
914      *      /"  Edit description (cr nc; / nc; ! truncate)",/)
915   197 FORMAT ( 21(""),A2,/,2X"Description"2/5(2X,36A2/)/)
916   198 FORMAT (2x,"",36A2,"",/,") _")
917   152 FORMAT (5A2)
918       END
```

Module CMNTS No errors Prog: 423 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Eqa: None

```
919 *
920 *                    1:18 PM  THU., 12  JAN., 1984
921       SUBROUTINE SAMPL (LOUT,IOPT), FBR      (850618.0956)
922 *
923 *     ------------------------------------------------------
924 *     STEADY STATE DATA ACQUISITION, REDUCTION AND PRINTING
925 *     ------------------------------------------------------
926 *
927       common idate(8),itest(8),irtc(4),
928      *       ichid(16,100),a(100),b(100),c(100),icode(100),
929      *       iscanner(100),ident(180),
930      *       xsect,height,strainrate,deformmax,contolint,
931      *       startleadtime,endleadtime,
932      *       poppetkh1,poppetkh2,poppetkh3,
933      *       proporkl1,proporkl2,proporkl3,
934      *       yieldest,dppropvalve,dpaccumloss,dplineloss,
935      *       offset(100),diethresh,boltthresh,numvalve,ivalve(6),
936      *       dpnom,strinit,gasvol,ipad(77),
937      *       volts(100),data(100)
938 *
939       DATA IHC,ICD,IUND /15550B,15512B,137B/
940 *
941       L=1
942       IF (LOUT.EQ.6) L = 6
943       IF (LOUT.EQ.6) GOTO 2
944       call scan (volts)
945       call calc
946 *
947       CALL SYTIM (2,IRTC,IDATE)
948 *
949 *     SAMPLE AND DISPLAY DATA
950 *
951       WRITE (1,104)      IHC
952     2 WRITE (L,100)      IDATE,ITEST,IRTC
953       WRITE (L,107)
954 *
955       WRITE (L,101)
956       WRITE (L,103)      (DATA(I), I=1,65)
957       WRITE (L,102)
958       WRITE (L,103)      (VOLTS(I),I=1,65)
959       if (lout.eq.6)     WRITE (L,105)
960       RETURN
961 *
962 *          ------------------
963 *          ALL FORMATS FOLLOW
964 *          ------------------
965 *
966   100 FORMAT ( ///,5X,"Date: "8A2,/,5X,"Test: "8A2,
967      .         25X,"Time: "12":"12":"12"."12)
968   101 FORMAT ( / 5X"Engineering Units" )
969   102 FORMAT ( / 5X"Voltages" )
970   103 FORMAT (5(/,1X,10(F6.5,1X)))
971   104 FORMAT (A2)
972   105 FORMAT ("1")
973   107 FORMAT (/,12X,"H Y D R A U L I C  P R E S S   S U P",
```

```
974      *                *E R V I S O R*)
975      END
```

```
Module SAMPL            No errors     Prog:   269    Blank Common: 3328
FTN77X 2326/830607      No warnings   Save:   None   Local Eqa:    None
```

```
976 *
977       SUBROUTINE SCAN (VOLTS)
978 *
979 *      In real application - calls to Taurus modules would be here
980 *
981 *      Must include common block, and map scanner channels to data channels
982 *
983       dimension volts(100)
984 *
985       do 1 i = 1,100
986     1 volts(i) = float(i / 20)  + float (i-1) / 100.0
987       return
988       end
```

Module SCAN No errors Prog: 51 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Eqa: None

```
 989 *
 990       SUBROUTINE CALC
 991 *
 992       common idate(8),itest(8),irtc(4),
 993      *       ichid(16,100),a(100),b(100),c(100),icode(100),
 994      *       iscanner(100),ident(180),
 995      *       xsect,height,strainrate,deformmax,contolint,
 996      *       startleadtime,endleadtime,
 997      *       poppetkh1,poppetkh2,poppetkh3,
 998      *       propork11,propork12,propork13,
 999      *       yieldest,dppropvalve,dpaccumloss,dplineloss,
1000      *       offset(100),diethresh,boltthresh,numvalve,ivalve(6),
1001      *       dpnom,strinit,gasvol,ipad(77),
1002      *       volts(100),data(100)
1003 *
1004       do 10 i = 1,100
1005       voltnet = volts(i) - offset(i)
1006       eng     = a(i)  + b(i) * voltnet + c(i) * voltnet**2
1007       arg     = b(i) * voltnet
1008       if (ichid(1,i).eq.2hTC) eng = typek (a(i),arg,1)
1009    10 data(i) = eng
1010       return
1011       end
```

Module CALC No errors Prog: 113 Blank Common: 3328
FTN7X 2326/830607 No warnings Save: None Local Eqa: None

```
1012 *
1013       SUBROUTINE VOFST
1014 *
1015       common idate(8),itest(8),irtc(4),
1016      *       ichid(16,100),a(100),b(100),c(100),icode(100),
1017      *       iscanner(100),ident(180),
1018      *       xsect,height,strainrate,deformmax,contolint,
1019      *       startleadtime,endleadtime,
1020      *       poppetkh1,poppetkh2,poppetkh3,
1021      *       propork11,propork12,propork13,
1022      *       yieldest,dppropvalve,dpaccumloss,dplineloss,
1023      *       offset(100),diethresh,boltthresh,numvalve,ivalve(6),
1024      *       dpnom,strinit,gasvol,ipad(77),
1025      *       volts(100),data(100)
1026 *
1027       data kchan,ks,kend/1,1,100/
1028 *
1029       iopt = 0
1030       write (1,100) offset
1031    10 write (1,101)
1032       call  iget (1,iopt)
1033       if (iopt.lt.1.or.iopt.gt.6) goto 60
1034       goto (60,20,30,40,50,60), iopt
1035 *
1036 *     option
1037 *      1: keep current offsets        4: by range
1038 *      2: zero all offsets            5: by channel
1039 *      3: take all channel offsets
1040 *
1041    20 do 21 i = 1,100
1042    21 offset(i) = 0.0
1043       goto 55
1044 *
1045    30 call scan (volts)
1046       do 31 i = 1,100
1047    31 offset(i) = volts(i)
1048       goto 55
1049 *
1050    40 call scan (volts)
1051       write (1,103) ks,kend
1052       call iget (2,ks,kend)
1053       do 41 i = ks,kend
1054    41 offset(i) = volts(i)
1055       goto 55
1056 *
1057    50 call scan (volts)
1058       write (1,104) kchan
1059       call iget (1,kchan)
1060       offset(kchan) = volts(kchan)
1061 *
1062    55 write (1,100) offset
1063       write (1,102)
1064       read  (1,134) ians
1065       if (ians.eq.2hn .or.ians.eq.2hN ) goto 10
1066 *
```

```
1067   100 format (/"  Offset voltages",//,5(/,10(1x,f6.5)))
1068   101 format (/"  Offsets menu:",//,
1069      . "     1: keep current offsets        4: by range",/,
1070      . "     2: zero all offsets            5: by channel",/,
1071      . "     3: take all channel offsets ",//,
1072      . "     enter option                    [1] ... _")
1073   102 format (/"  Offset voltages satisfactory [Y/N] ... Y_")
1074   103 format (/"  Enter first and last channel  ["i3","i3"] ... _")
1075   104 format (/"  Enter channel # ["i3"] ... _")
1076   134 format (a2)
1077    60 return
1078       end
```

```
Module VOFST            No errors     Prog:  445   Blank Common: 3328
FTN7X  2326/830607      No warnings   Save:  None  Local Eqa:    None
```

```
1079 *
1080 *                    2:34 PM  THU., 17  FEB., 1983
1081       FUNCTION TYPEK  (rj,x,iopt), FBR      (850618.0956)
1082 *
1083 *      ------------------------------------------------
1084 *      Temperature conversion for type K thermocouples
1085 *      ------------------------------------------------
1086 *
1087 *
1088 *       X  = MILLIVOLT READING
1089 *       RJ = REFERENCE JUNCTION OFFSET VOLTAGE
1090 *            * 2.661 for type K  if ref junction is at 150 F
1091 *       IOPT = 1 CONVERT TO DEG F FORM CELCIUS
1092 *
1093       XRJ=X+RJ
1094 *
1095 *     ------------------------------------------------------------------
1096 *     TYPE K CONVERSIONS
1097 *     FOR BOTH FITS ERROR IS LESS THAN 0.1 DEG C (FOR 0 -> 1360 DEG C)
1098 *     ------------------------------------------------------------------
1099 *     .
1100        IF(X-9.54) 2,2,3
1101      2 typek=0. + 25.3785*XRJ - 0.367381*XRJ**2 + 0.525851E-2*XRJ**3
1102       * + .115284E-1*XRJ**4 - 0.136196E-2*XRJ**5 +0.449284E-4*XRJ**6
1103        GOTO 99
1104      3 typek=3.10178 + 23.4898*XRJ + .214420*XRJ**2 - .180069E-1*XRJ**3
1105       * + .592619E-3*XRJ**4 - .858503E-5*XRJ**5 + .479096E-7*XRJ**6
1106 *
1107 ****  if t/c is open circuit --- > reset temperature to defaults value
1108 *
1109     99 IF (typek.GT.2000.OR.typek.LT.-100.0) typek = 0.0
1110        if (iopt.eq.1) typek = 32.0 + typek * 1.8
1111        END
```

Module TYPEK No errors Prog: 214 Blank Common: None
FTN7X 2326/830607 No warnings Save: None Local Eqa: None

APPENDIX V

COMPUTER CONTROL AND HARDWARE SPECIFICATION INFORMATION

Taurus Proposal Document No. ES85017

The DEC Professional 350

Taurus Lab Product Overview

TAURUS COMPUTER PRODUCTS INC.

1755 Woodward Drive.
Ottawa, Ontario.
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(613) 226-5361

Proposal for Computer Control of a Hydraulic Ram

Proposal and Specification

TAURUS COMPUTER PRODUCTS INC.

Document No: ES85017
Created: 24-MAR-85
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Revision: B

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A.1 Data Acquisition and Control Equipment - Taurus Computer Products Inc.

A.2 Host Computer System - Digital Equipment Corp.

PROPOSAL FOR COMPUTER CONTROL OF A HYDRAULIC RAM

1.0 Introduction

This document is a proposed outline for a computer controlled data acquisition and control system for a existing press system. In order to add automatic control to this press, the existing system will be blocked in position. A new 450 ton Hydraulic Ram will be installed on the lower portion of the existing equipment. This Ram will push up against the upper platen which is locked in one position. This new Ram will include its own hydraulic system as well as the Data Acquisition and Control equipment to allow:

- the user to initiate tests which apply constant strain onto a test sample. The user defines the desired strain, initial sample length and maximum deformation. He will be allowed to modify control parameters so as to give the best possible results. Experiments will be monitored and actual results will be plotted and compared to theoretical ones. All this is accomplished with operator interfacing to a host computer system

- safety lockout of computer control of ram during sample loading and other maintenence tasks.

The system outlined in this document includes only the electronic and computer components. It is based on the assumption that the hydraulic requirements, control valves, etc. will be supplied as required by the Contract Engineering group of the Nuclear Products Department of Westinghouse Canada Inc.

It should be noted here that the control strategy and algorithm for the press control outlined in this document may require further refinements once it is tested on the actual equipment. It is anticipated that the implementation of this scheme will require a commissioning period during which the algorithm parameters may be more tightly defined and the algorithm itself may be slightly modified. This period of development was designed into the cost of development as this is believed to be one of the first such automations of this type of press.

2.0 System Overview

Figure 1 shows a block diagram of the components involved in the system. The existing hydraulic press is shown with a block that represents the addition of the 450 ton hydraulic Ram. The data aquisition and control equipment required for this will be three TAURUS ONE/10 systems. They will monitor and control various points in the new

system to be added to the press. They are connected, using a serial link, to a host computer. It is through this host that the tests are initiated by the user, commands and parameters are sent to the TAURUS units, results are returned from the TAURUS units and test data is displayed for the user.

The purpose of this system is to apply a constant strain on a sample in the press using the main ram. The sample may be a variety of material types and may exist at a wide range of temperatures. There is an oven to the left front of the press from which samples may be taken. This is done by an operator using a pair of long tongs to remove a sample from the oven and place it in the press.

Because of safety considerations it is extremely undesirable to have any ram movement during the time that samples are manually loaded or unloaded from the press. For this reason, the system will include a keylock interlock switch and a large stop push button. The keylock would be moved to a safe position, disengaging computer control of the ram, before any manual work is done about the press. The push button allows any person to quickly disengage computer control at any time.

The user utilizes the system through the host computer. He may run a test by specifying a number of Press Control Parameters. Such parameters are defined using a number of 'menus' presented the user on the computer's console. These 'menus' are discussed in greater detail elsewhere in the system specifications. Having described all parameters, the operator need do no more as the computer will make all required calculations and send a series of command messages to the TAURS ONE units. Upon command from the host, the TAURUS units will begin the control run without intervention from the host. Once the test is completed, results are returned to the host for analysis and display.

Control of the ram movement is obtained by controlling oil flow with a number of poppet and proportional valves. These valves modify oil flow from a set of accumulators which are used to maintain the pressure during the test run.

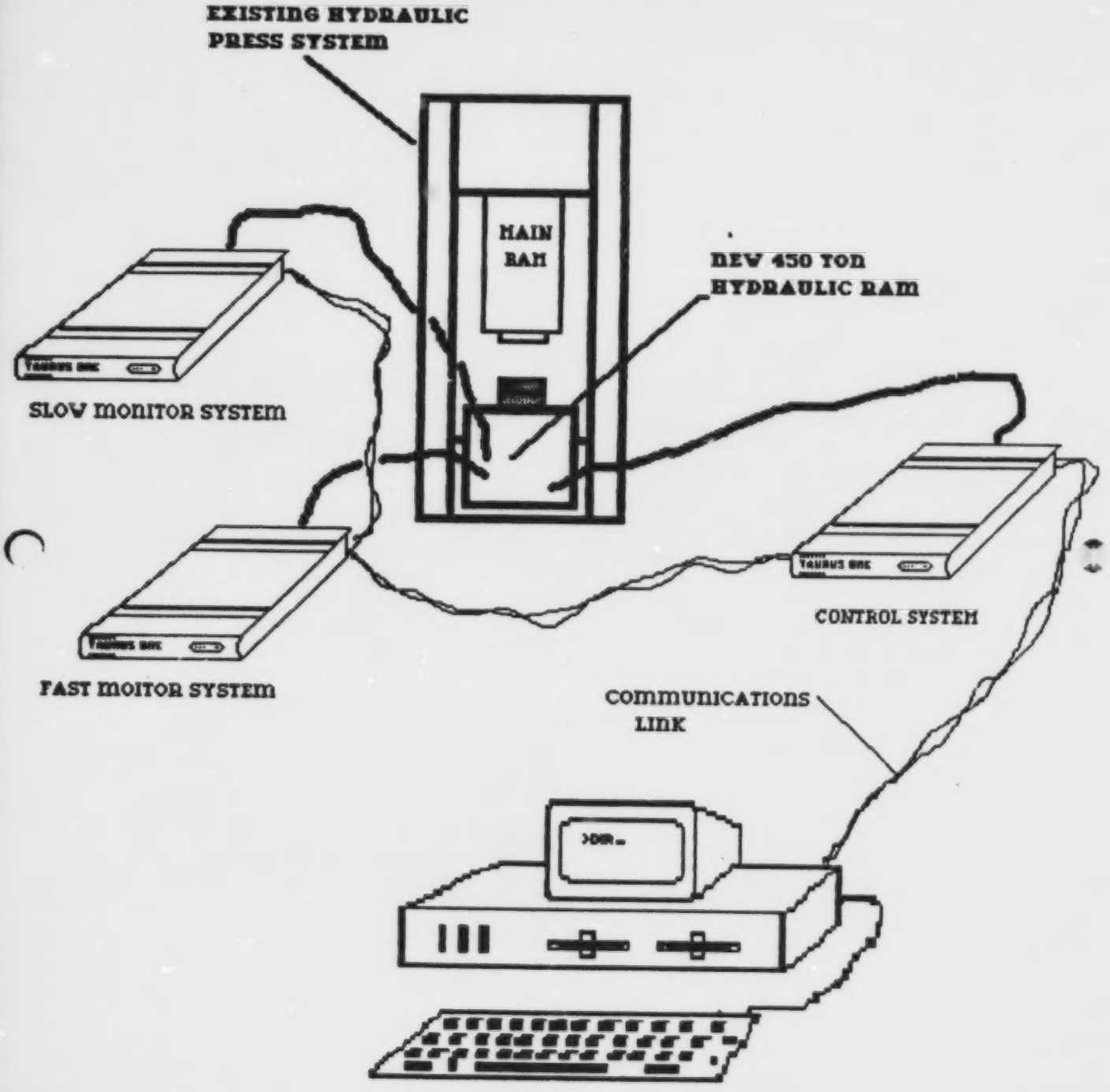


FIGURE 1 - SYSTEM BLOCK DIAGRAM

The input and output signals for the ram have been divided into three major groups according to their functionality. The valve controls, ram position and oil pressure have been assigned to one unit which will be responsible for the ram control during the test run. This unit will be loaded with a position curve plus control parameters. It will initiate a test upon command from the host computer. During the run it will monitor ram position and modify control signals to the valves based on this position and the loaded parameters. The experiment will be terminated by this unit upon expiration of a preset time limit or else a detected drop in the oil pressure.

A second group of signals have been assigned to a fast monitor system. The purpose of this system is to monitor a number of signals during the test. These will be monitored on exact time intervals so that curves may be plotted after the test run showing the actual results versus time. This system will monitor signals on an interval as short as 3 milliseconds.

The third group of signals are a number of temperature probes to be placed throughout the press and recorded throughout the test as well as some valve status points. These are not part of the monitor system as these points will not change rapidly enough to warrant monitoring them at the same speed as the other signals. These signals also may be sampled at a specified interval throughout the test, however the minimum interval for these points will be 15 milliseconds.

These three systems are linked to a host computer with a multi-dropped serial communications line. This host computer includes a video terminal for interfacing with the user of the system. Using menus displayed on the screen the user may initiate a test run. To do this, he will enter the material and the test parameters. Before the test is begun, the user will be asked to define the control parameters to be used during the run. These may be default values supplied by the program, historically proven values saved on disk files, values entered by the user himself or combinations of the above. Once the user is satisfied with these, they will be loaded into the control and monitoring systems. The actual test run will commence on command from the user, which is passed to the three machines. Once the test is complete, the data observed by the two monitoring units is uploaded into the host computer. Once there, the results will be plotted on the screen for the user. If desired, result summaries can be printed out on a printer.

3.0 Hardware Outline

It is recommended that a control area be set aside for the installation of the system as described in this document. It would be preferable that a separate room be reserved in close proximity to the press where an operator would initiate and monitor the tests. This would allow the development of a set of simple safety rules that will help prevent any operator from being too close to the ram during operation.

Except where noted, all of the equipment described in this document will be located in the control area. Wiring will connect the sensors to the appropriate interface circuit mounted in the control area.

The equipment to be supplied falls under one of three categories - the data acquisition and control equipment, the host computer system and the safety switch logic.

The data acquisition and control equipment will be mounted together in one free-standing cabinet. This cabinet will include rack mounting space conforming to EIA standards. The equipment to be installed in this cabinet includes:

- the three TAURUS systems (control system, monitor system and temperature system).
- signal conditioning equipment used to transform the sensor voltages levels to a higher level suitable for interface to the TAURUS equipment.
- a display panel to monitor the position or status of the valves and to allow manual manipulation of them.
- a panel for mounting of the saftey switch relay logic.

Appendix A.1 provides more detail on the specifications and description of the TAURUS equipment. As can be seen in this section each system will consist of two main parts - the TAURUS ONE/10 foundation unit including all required I/O modules and the signal termination panels. The TAURUS ONE/10 will be rack mounted using slides to allow access to the unit for calibration and maintenance. All modules within the TAURUS ONE/10 are mounted on hinges to allow easy access for 'in-situ' calibration. The termination panels include screw terminals for easy connection of field signal wiring to the system. These panels are mounted within rackmount enclosures.

Figure 2 shows the free standing cabinet with the proposed layout of equipment to be mounted therein.

The host computer system is more fully described in Appendix A.2. This system will not be mounted inside a cabinet, but will be suitable for desktop operation.

The last category of equipment relates to the safety switch logic. As alluded to in the System Overview it will be necessary to include a mechanism for an operator to shut off computer control of the ram at certain times. As well, there should be one or more push button switches mounted at appropriate places about the ram and control area that will allow anybody to quickly disconnect computer control of the ram.

Computer control of the ram is removed by disconnecting the power to the control valves. Figure 3 shows a proposed circuit which will accomplish this. This figure includes three different types of switches to be used by the operator. On the left is a switch labeled START PUSHBUTTON. This momentary contact switch is pressed to engage the automatic contol of the press. This switch will be located inside the control area. It will be necessary to press this switch once to allow for automatic control after disengagement by any of the other two switches or due to a power outage.

At the top left of the diagram is a three position keylock switch. It has three positions - automatic control (AUTO), computer disconnected (SAFE) and manual operation (MAN). It is recommended that this be a keylock switch so that it may be left in the safe position when not in use - with the key removed to prevent unauthorized tampering with the system. During normal operation, the key would be left in the lock to allow for free and quick access to this switch. This keylock would be located in the control area and is used to ensure the computer control is not enabled during the time that any operators are working near the press.

The third type of switch is a momentary contact type labeled in the diagram STOP PUSHBUTTON. Pushing of this switch will immediately disengage the computer control of the press. It should be noted that any number of stop switches may be put in series with this switch without any effect on the operation of the circuit. Such buttons should have large actuators and it is likely that two should be included in the system - one mounted near the press itself and one in the control room. However, more could be added if it was deemed that this would improve the safety of the system.

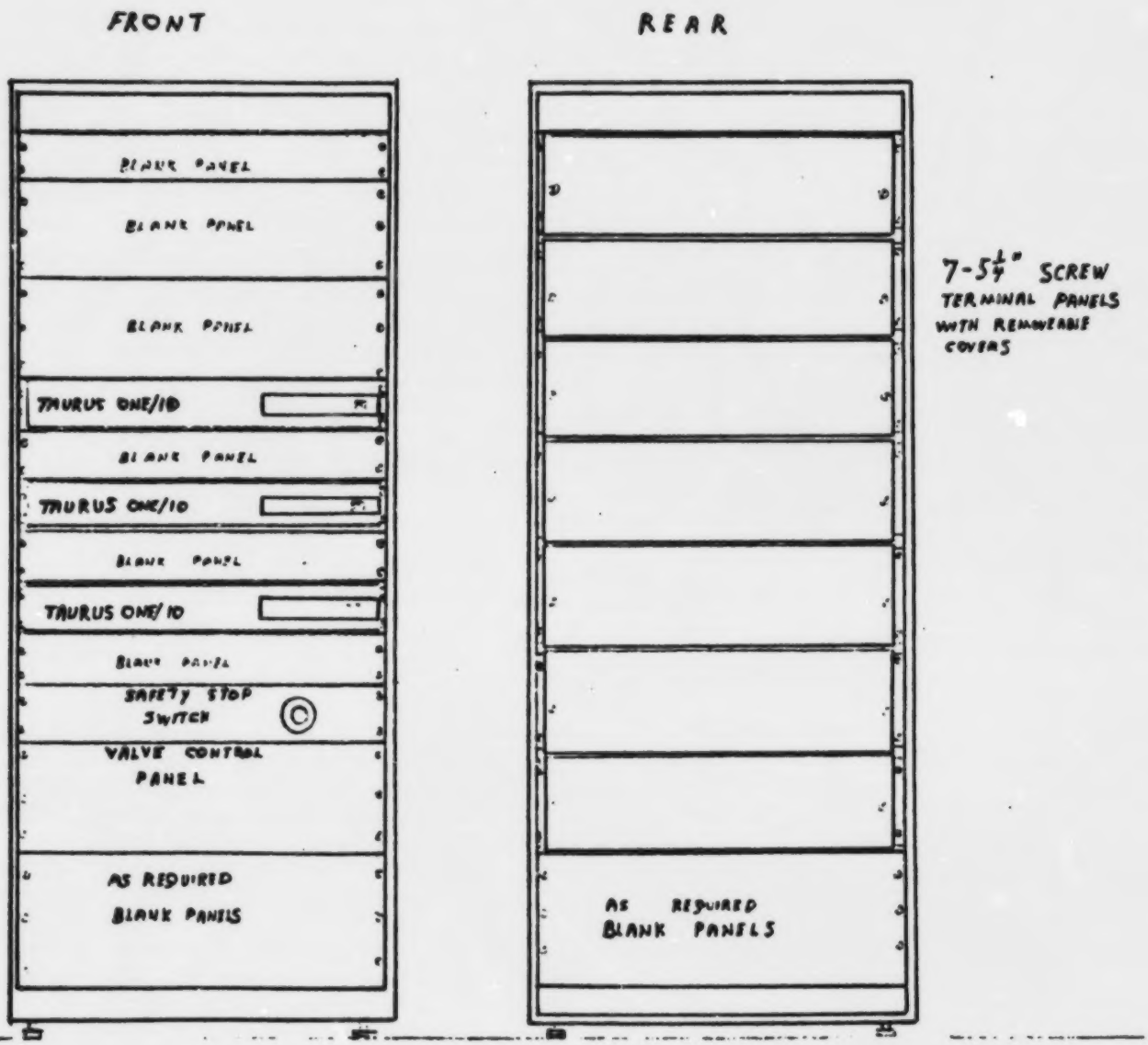


FIGURE 2 - CABINET LAYOUT

The logic of the circuit will turn on a relay used to provide the power for the poppet and proportional valves. In the event of power loss to the system, pushing of any stop button or turning of the keylock from the AUTO position, the contacts to power the valves will open. They will remain open until power is restored, the switches are back in a normal position and the START PUSHBUTTON is pushed.

Another set of contacts on the valve power relay are connected to the control system. In the event that this system detects that power is not being applied to the valves, it will immediately stop any ram movement.

All of the circuit shown in Figure 3 would be mounted on a panel to be included in the control cabinet. This panel would also contain the keylock switch, the start switch and one of the stop switches. Note that the circuit includes a LED to indicate the status of the power to the valves. This would also be mounted on the panel for the information of the operator in the control area.

3.1 Press Control Hardware

Figure 4 shows an outline of the hydraulic system used to drive the ram. The ram position is controlled by the oil flow through the proportional valves V1 - V6. Not all valves will be used during any one test. The valves chosen will depend on the test requirements. These will be selected by the host computer based on the parameters selected by the operator. They will be moved to their initial position with the poppet valves V7 and V8 closed. Once the run is intiated, the appropriate valve is opened (V7 or V8). The flow is modulated by control signals sent to the proportional valves. Upon conclusion of the test valves V7, V8 and V9 are closed. Any pressure spikes are limited to 5000 PSI by the spring loaded poppet valves V10 and V11.

4.0 The Control System

As shown in Figure 1, one of the TAURUS systems is designated as the control system. This system is responsible for the control output to the poppet and proportional valves during the test. It will also monitor the pressure, time and valve power to determine if a test should be stopped.

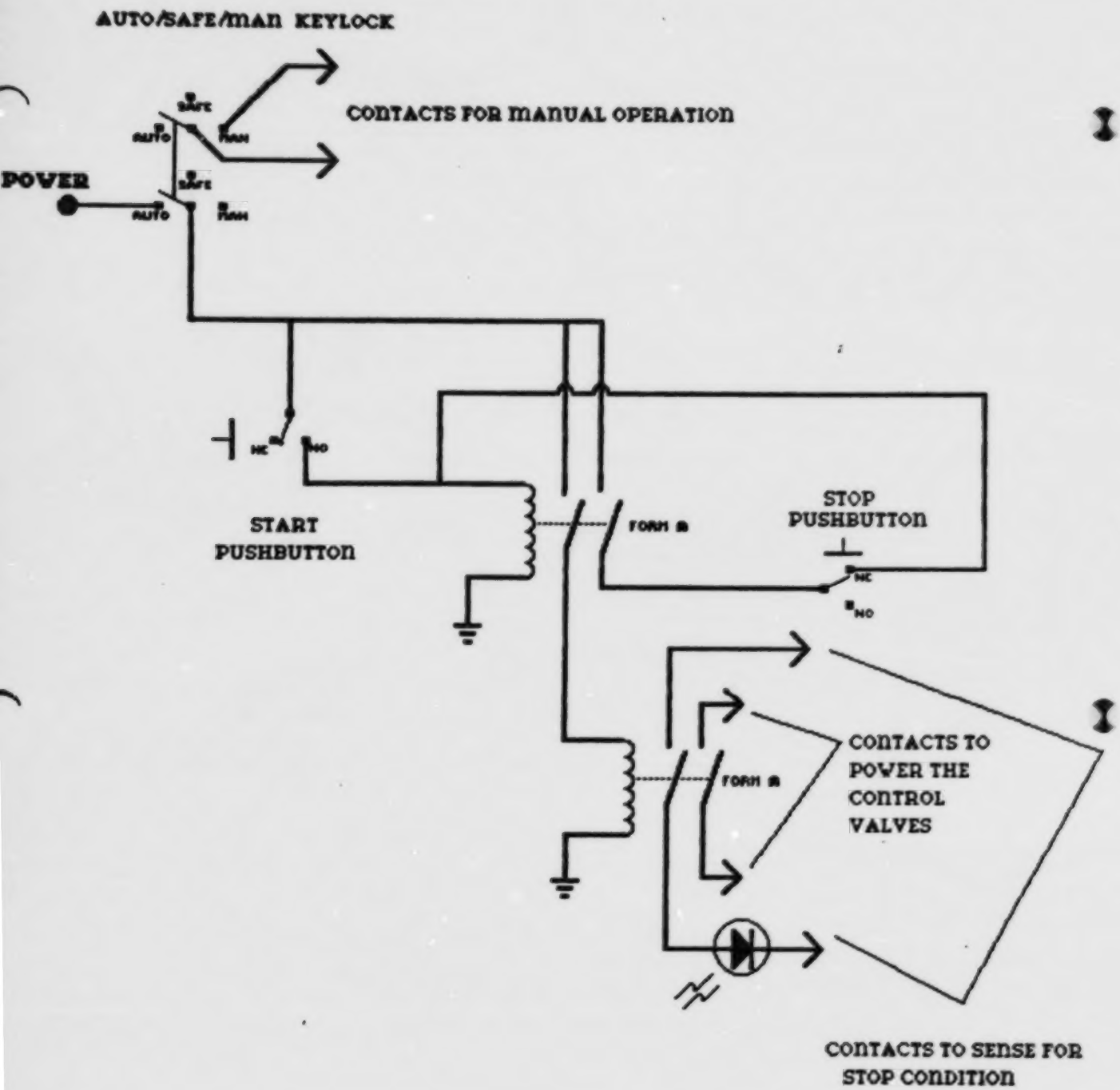


FIGURE 3 - SAFETY SWITCH LOGIC

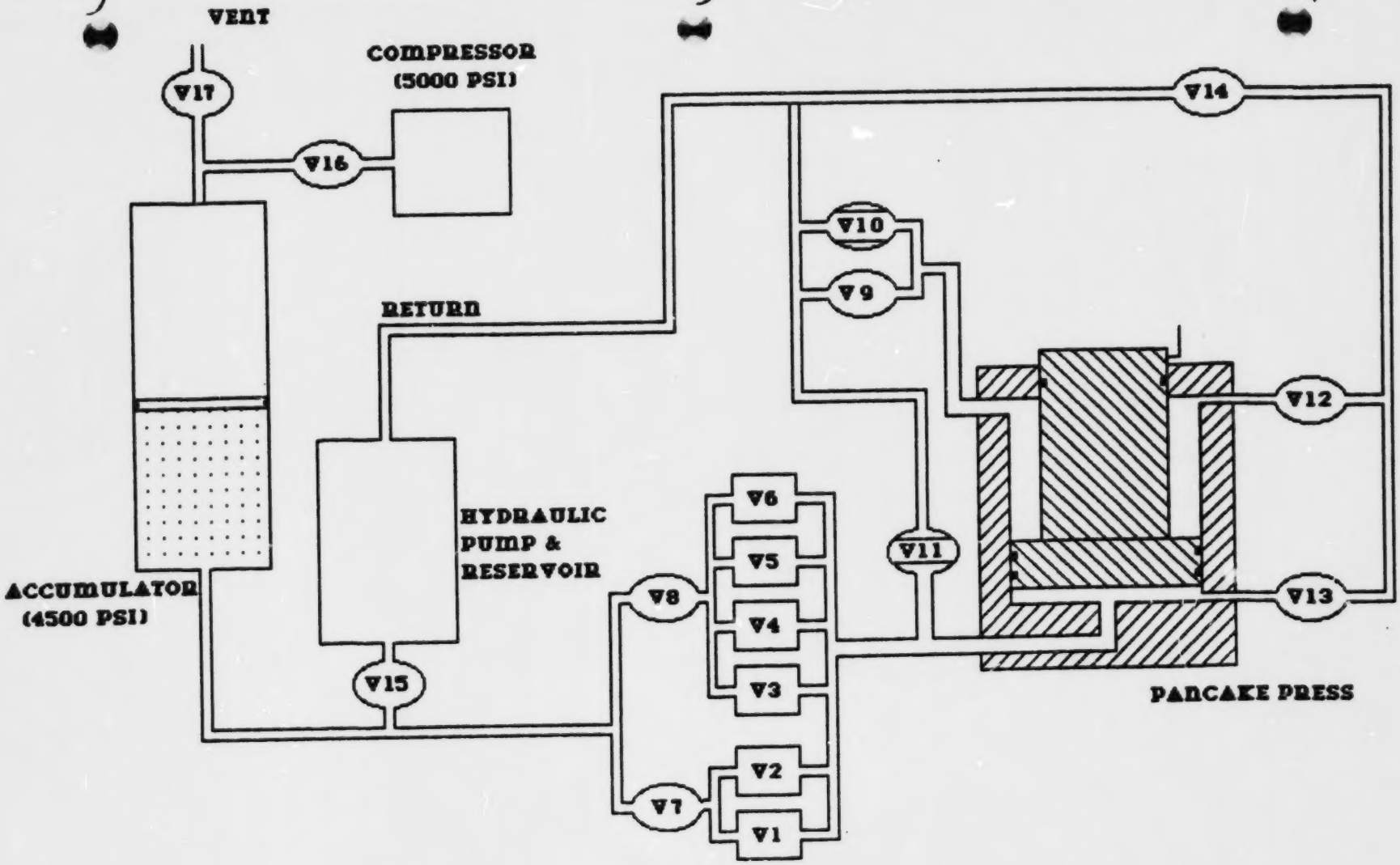


FIGURE 4 PRESS CONTROL DETAIL

Figure 5 shows the Press Control Detail with the addition of the points that this system will monitor and control. The unit will provide analog control signals to the proportional valves V1-V6 and digital control signals to poppet valves V7-V9. It will monitor the Ram position as its control variable and the inlet pressure, It will use this inlet pressure to monitor for test billet structure shearing. Outside of the Press Control this unit monitors the Safety Circuit Status and provides a digital signal to the other two units which is used to indicate when a test is in progress.

4.1 Components

Figure 6 shows a diagram representation of the control system. Each of the components of the system is described in the following sections in greater detail.

4.1.1 TAURUS ONE/10

At the heart of this system is the TAURUS ONE/10. This is a remote data acquisition system which communicates to a host computer over one of two serial links or a IEEE488 port. The unit is based around a Z80A processor module which contains 24K bytes of pre-programmed firmware, 8K bytes of system RAM memory and sockets for 32K bytes of user program or data storage. It contains, as peripherals, the communication ports (2 serial, one IEEE488), counter/timers, watch-dog timer and a TAURUS BUS interface port. The unit is self-contained in a metallic enclosure and includes its own power supply. It may be used on a table top or else rack mounted with optional slides.

The TAURUS BUS is a flexible bus structure which allows up to 16 TAURUS BUS I/O modules to be connected to the processor module. Up to three modules may be added to the TAURUS ONE/10, others are added using expander chassis. TAURUS manufactures a wide range of I/O modules which are TAURUS BUS compatible. Two of these are used in this system.

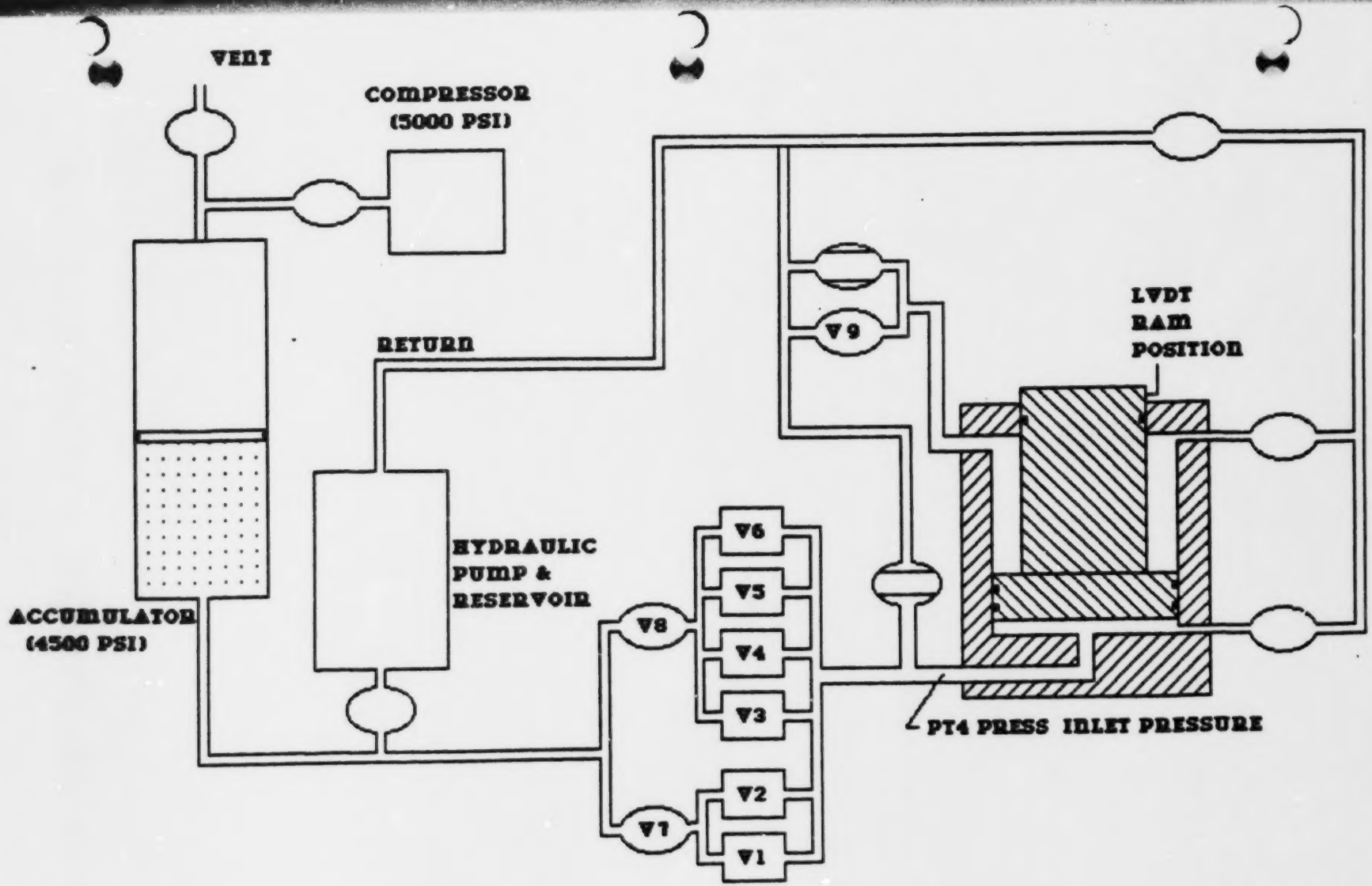


FIGURE 5 - CONTROL SYSTEM I/O POINTS

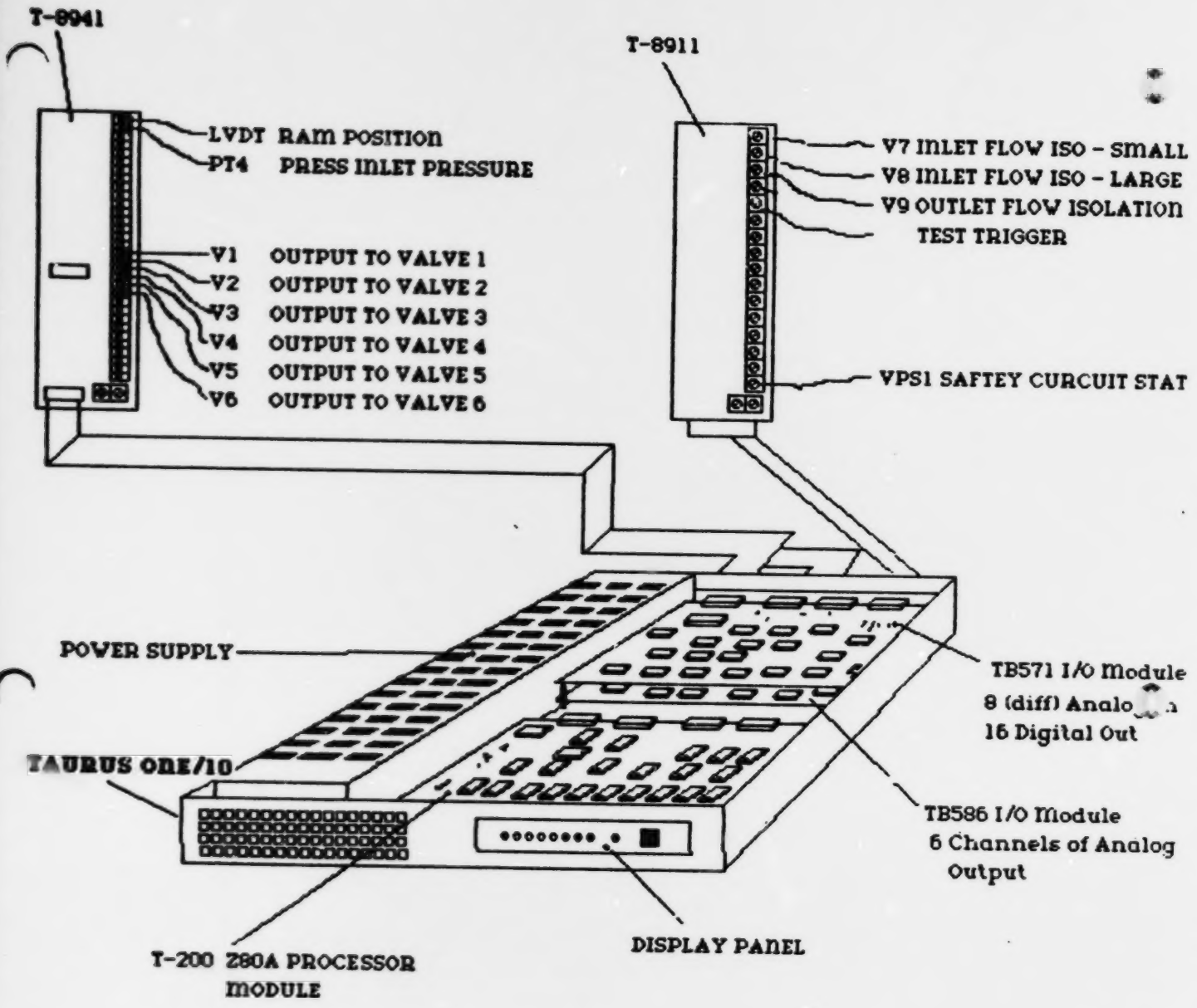


FIGURE 6 - CONTROL SYSTEM - BLOCK DIAGRAM

4.1.2 TB571 TAURUS BUS Module

The TB571 is a TAURUS BUS module with a combination of analog and digital I/O. It contains 16 bits of digital input/output bits. These bits are at TTL levels. Using jumper links on the module, the digital bits may be set up as input or output in groups of eight. This means the module may be configured with 16 output bits, 16 input bits or 8 input / 8 output bits.

This module has one connector for all 16 digital signals.

The analog system is based around a 12 bit successive approximation Analog to Digital Converter (A/D). Up to 16 single ended or 8 differential signals may be input on this module. Each channel has a gain selected for it (in firmware) that is either 1 or 201. The module has the capability of interfacing to a terminal temperature sensor which allows (in differential mode) any one of the input channels to be directly connected to a thermocouple of type J,K or T.

The A/D has the capability of having its input jumpered selected as +/- 10V, +/- 5V, +/- 2.5v, 0-10V or 0-5V.

This module has a second connector for these analog input signals.

4.1.3 TB586 TAURUS BUS Module

The TB586 is a TAURUS BUS module with 6 channels of Analog Output signals. These signals are voltage outputs and each channel may be jumpered for a range of +/- 10V, +/- 5V, +/- 2.5v, 0-10V or 0-5V.

The Digital to Analog Converter (D/A) has a resolution of 12 bits.

This module has a single connector for the 6 output signals.

4.1.4 Termination

The philosophy of field signal termination is the same for all types of TAURUS BUS modules. All signals are terminated at modules located outside of the TAURUS ONE/10 unit. These modules all contain screw terminal strips, the capability for a limited amount of passive termination and a cable to connect the module to the appropriate TAURUS BUS module.

4.1.4.1 T-8911

This panel allows for 16 digital input or output signals to be connected to a TAURUS ONE system. In this system, it will connect to the TB571. Eight of its signals will be outputs and the other eight will be inputs. One of the input signals is used to sense the state of the valve power. This input will have signal conditioning components installed such that this input will be able to sense contact closures. All signal will be TTL levels.

4.1.4.2 T-8941

The T-8941 allows up to 16 differential or 32 single ended signals to be connected to a TAURUS BUS module. As all of the TAURUS BUS analog modules have connectors which carry 16 SE/8 DIFF signals, this module has two connectors and cables. One will go to the TB586 to interface to the 6 analog output signals, while the other will go to the TB571 with the analog input signals.

4.2 The Control Problem

The two major tasks to be performed by the control system have been previously outlined as the control of the ram during a test and the determining of the termination of the test. The task of controlling the ram forms a major problem to be solved by this system.

The operator begins a test run by defining the strain, initial length and deformation to be applied to a sample. From this data, a graph of the desired ram displacement versus time be calculated. During the test, the ram must be made to follow this curve as closely as possible.

The ram may be controlled using a hydraulic system as was shown in figure 4. The ram's position is controlled by varying the velocity of the ram. The ram velocity is directly proportional to the oil flow. The formula relating the two is as follows:

$$\text{Oil Flow} = \text{Ram Area} * \text{Ram Velocity}$$

where Ram Area = 20i square inches

The basic control problem is summarized in block diagram form in figure 7. The present ram position is obtained by the TAURUS unit. Using a control algorithm, the present position as compares to a new desired position results in a new voltage level output to the control valves. The valves change the amount of their opening due to the

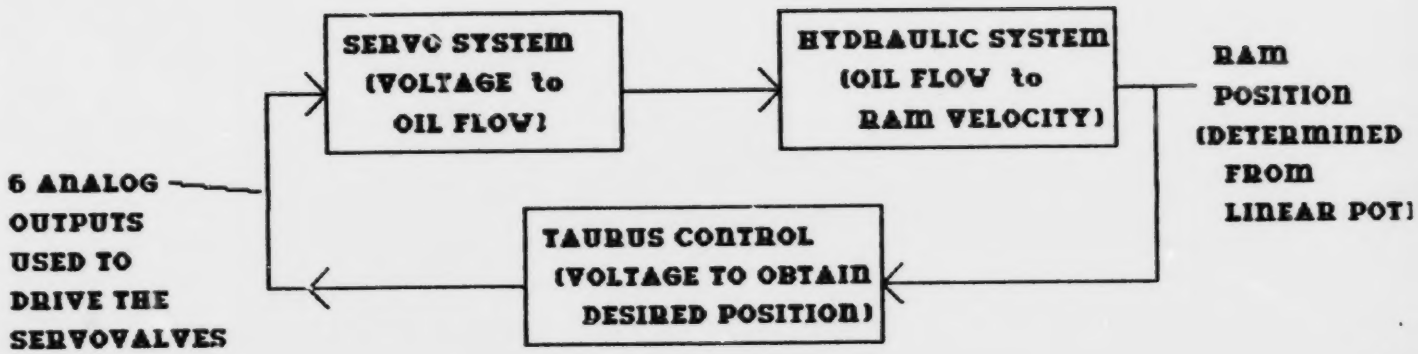


FIGURE 7 - THE CONTROL PROBLEM

changed control input. This will change the amount of the oil flow through to the ram. This change in the oil flow will result in a change in the ram velocity, hence its position at the next sample will be different. The problem to be solved is to design an algorithm which will maintain the ram on a predefined path.

The system designated as the control system is a Z80A micro computer. All programming done on this system is done in assembly language. For this reason, it is somewhat arduous to program algorithms with many complex calculations.

As well, the control system must closely monitor the oil pressure of the press and stop the test once any drop is detected in this signal. It is critically important that the control system have as short a reaction time as possible from the drop in pressure to the stopping of the test.

As mentioned above, control is accomplished through output of an analog voltage to six control valves. The percent that these valves are open is directly proportional to the oil flow required through them. These valves will be divided into two groups. V1 and V2 will carry smaller amounts of the flow. V3 - V6 will carry a larger amount of the flow. The control algorithm designed for the control system will not output a unique voltage for each of these valves. It will calculate two numbers - one for all the larger flow proportional values (0 high), and one for the smaller flow valves (0 low).

Based on the considerations outlined above, the algorithm will require that most of the calculations be done before the test begins.. This being the case, these calculations will take place in the host computer where the availability of higher level languages will facilitate the coding of the calculations required for the algorithm.

The host computer begins by calculating a ram position versus time relationship. From this, a control interval can be defined. This interval is the time between actual control outputs. The host may then calculate what the desired ram position is for each of the expected intervals during the test. These are loaded down into the remote unit. The control unit will be outfitted with 32K bytes of RAM memory to store such data. This will allow any number of intervals up to 1200 to be defined for the test. The intervals may be any integer number of milliseconds from two to 65535.

After calculation of the desired ram position, a list of theoretical oil flow will be calculated by the host. This is the oil flow to achieve the desired velocities to result in the defined ram position curve. These calculated values will be then loaded down to the control system.

(It should be noted at this point that the numbers loaded into the control system will not be in engineering units, but will be numbers in the range of the output of the A/D or the input of the D/A. This will require the host to do this calculation before the test and will relieve the control system of this chore. These numbers will be transparent to the operator as he will never see them.)

The test run begins by the control system setting the output high or low values to their initial position as defined by the data sent from the host. Once this position is confirmed, the valves to the accumulator (see Figure 4) are opened by the control unit and the test begins.

Once the test has commenced, the control units will spend all of its time concerned with the test. All communication interrupts, clock interrupts and other tasks will be ignored during this time.

During the intervals between the control output, the unit will monitor the time, pressure and the valve power status. If any of these so indicate, the test run will be stopped. This is accomplished by simultaneously closing the poppet valves on the output of the accumulator and closing the release valve on the press. The ram pressure is then vented manually.

At the control interval a new high or low output value will be calculated. This will be done based on the following formula:

$$Ohigh = Ohigh\ (last) - TVhigh - EShigh$$
or
$$Olow = Olow\ (last) - TVlow - ESlow$$

where

Ohigh	-	is the number to be output to the large flow valves
Olow	-	is the number to be output to the small flow valves
Ohigh (last)		is Ohigh output on the last interval
Olow (last)		is Clow output on the last interval
TVhigh	-	is the theoretical number sent from the host to be used to calculate the large flow output on this interval
TVlow	-	is the theoretical number sent from the host to be used to calculate the small flow output on this interval

where

ESHigh - Error factor
ESlow - Error factor

Note that the theoretical number sent from the host is not an absolute value, rather it is a change in value from the previous output.

The error factors allow for the modification of the control output based on a error signal. These are defined as follows:

ESHigh = Kh1*Et + Kh2*En + Kh3*Es

ESlow = Kl1*Et + Kl2*En + Kl3*Es

where

Et is Desired Position - Present Position
En is Next Desired Position - Present Position
Es is sum of this plus last two Et
Kh1,Kh2,Kh3,Kl1,Kl2 & Kl3 are constants supplied from the host before the control begins.

In some cases the interval between control will be too small to allow these calculations to be made between control outputs. In these instances the error factors ESHigh and ESlow would be set to zero. Although it is impossible to define exactly, it is anticipated that the minimum interval for this type of feedback control will be 15 milliseconds.

4.3 Functionality

The control system will be equipped with the standard functionality as described for the TAURUS ONE/10 in Appendix A.1 of this document. In addition, special functions will be added to the firmware to allow for the encoding of the control algorithm as outlined in Section 4.2.

(Note: for a full understanding of this section the reader should be familiar with TAURUS ONE functions and protocols. Those readers unfamiliar with these should reference a TAURUS ONE user or technical reference manual or else review a TAURUS ONE or TAURUS LAB product overview.)

Functions are briefly described in this section. They are shown only in their ASCII protocol although all will be available in both ASCII and Binary formats. The functions all include an id term which defines a unit identification and are terminated with a carriage return.

Functions will be added which will allow the host system to send data and parameters required for the test run. Their syntax will be as follows:

Define Parameters **$A@ id DP (para,data)**

This function will define the parameter values to be used in the control of the ram. para is the parameter number and data is the value defined for the parameter. Once defined, these values remain until changed by this function. Parameters are initialized at 0.

PARA	DEFINES
1	Control Interval (milliseconds)
2	Pressure Difference which will constitute a test end
3	Maximum time for the test
4	Poppet valve to be used in the test (V8 or V7)
5	Valve Combination to be used in the test

Define Constants **$A@ id DC(kh1,kh2,kh3,KL1,KL2,KL3)**

This function is used to define the error constants as described above.

Add to Theoretical or Position Table **$A@ id AT [PS/HG/LW] (CL) (data,...)**

This is used to add to a table in the control unit data points to the ram position, the high theoretical output or the low theoretical output data saved in the control system. If the

CL argument is included, all previously saved data will be cleared out. One of the arguments PS, HG or LW will be used to define the data for the position, high values or low values tables, respectively. Any number of data words may be added to these tables.

Begin Test $A8 id BT

This will initiate a test run. This function will not respond until a test run is complete.

Once a test is initiated, it begins by shutting off all interrupts to the system. After initializing the control valves, the code will stay in a tight loop as diagramed in the flow chart shown in Figure 8. This control loop is designed to give the processor the smallest possible time constant. It is anticipated that the minimum control interval will be 2 milliseconds.

5.0 Fast Monitor System

This Fast Monitor System will be recording the values on a number of transducers on the press during the test run. These readings will take place at a defined interval to allow reconstruction of these values as they relate to time.

Figure 9 shows the Press Control Detail with the addition of those points to be monitored by this system. In addition to these points, the unit will be monitoring the Test Trigger line assorted by the control system.

Figure 10 shows a block diagram for the Monitor System.

5.1 Components

As can be seen from the diagram for this system, many of the components which make up this system are identical to those used in the Control System. The TAURUS ONE/10 and the TB571 are described in Sections 4.1.1 and 4.1.2 respectively.

FIGURE 8 - LOOP FLOW CHART

TAURUS COMPUTER PRODUCTS INC	DRWL Phil Carrillo		TITLE RAM Control System Control Algorithm Flow Chart		SHEET 1 OF 1	NUMBER	REV. A
	ENGL Phil Carrillo						

FIGURE 8 - 1 FLOW CHART

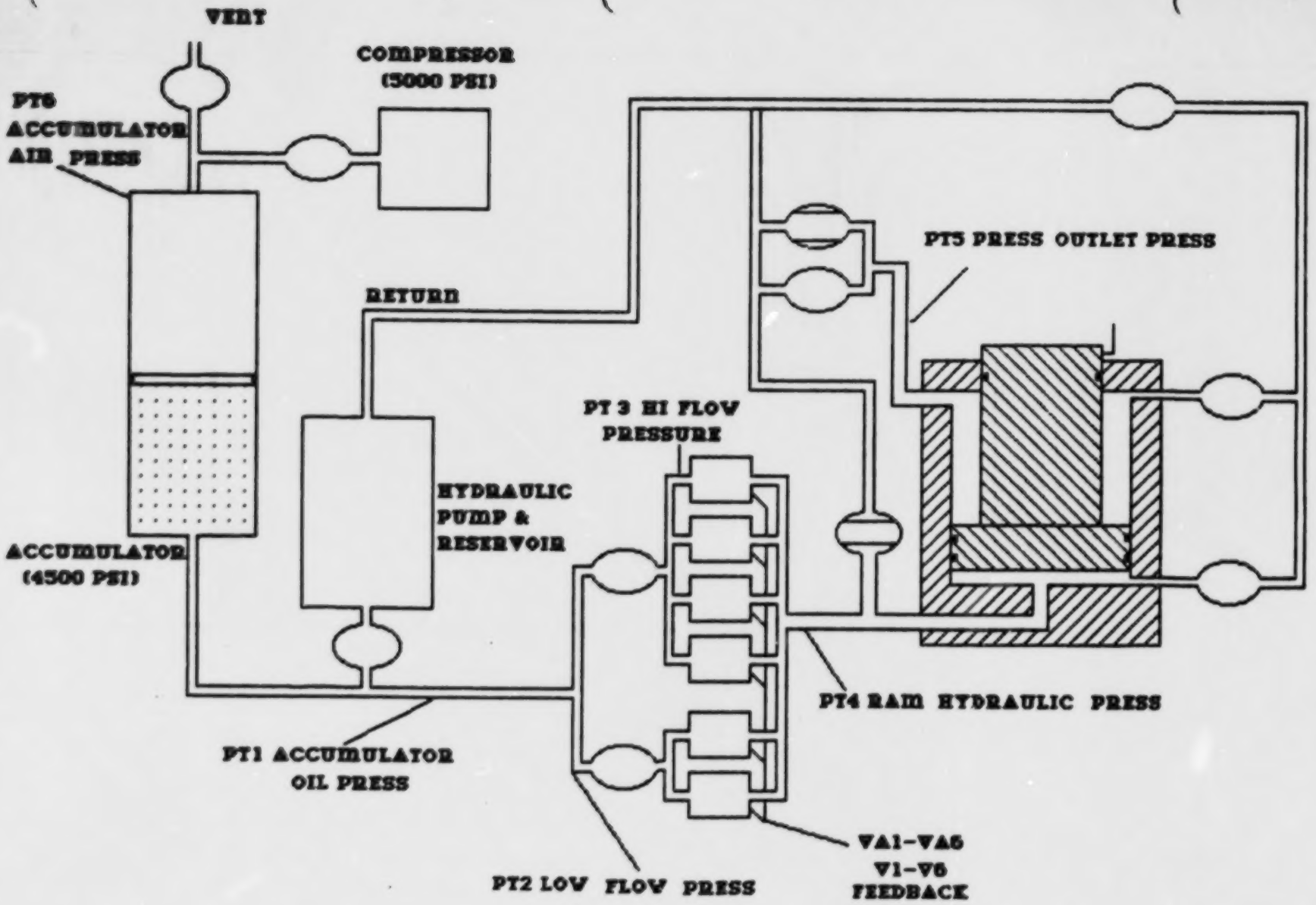


FIGURE 9 FAST MONITOR SYSTEM - MONITOR POINTS

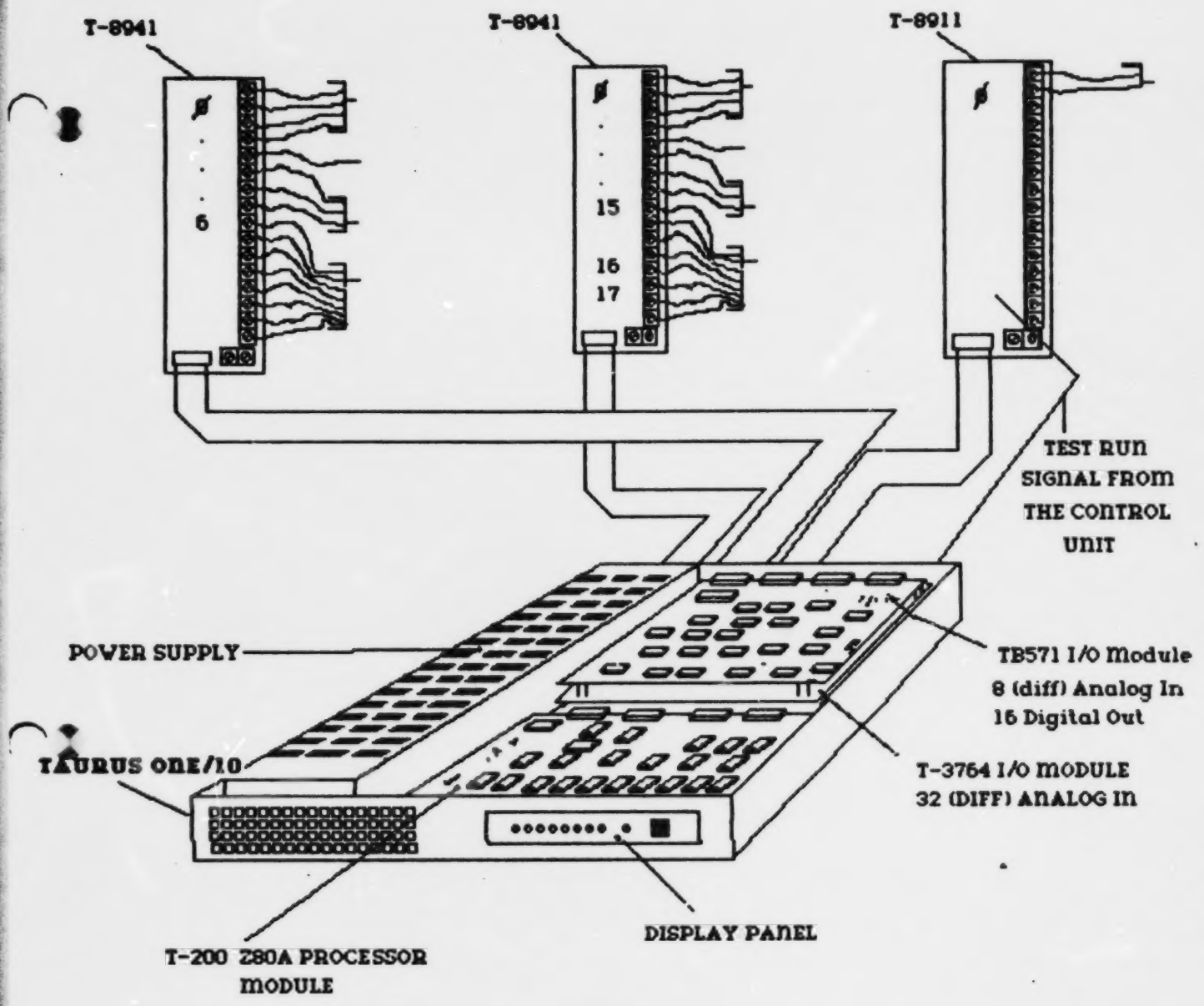


FIGURE 10 - FAST MONITOR SYSTEM - BLOCK DIAGRAM

The number of analog channels monitored by this system requires the addition of a T-3764 analog input module. This is a 64 single ended/ 32 differential input module. It uses the same 12-bit analog to digital converter as can be found on the TB571 module. However, it has the capability of three gains - 10, 100 and 1000 along with its unity gain. It is its unity gain which will be used in this application.

This module has no thermocouple capability but it may have its input jumpered for +1-10V, +1-5V, +1-2.5V, 0-10V or 0-5V range.

This system will use two T-8941s and one T-8911 termination panels.

5.2 Functionality

The role of this system is to monitor the defined points during the test time. The functionality here is the same as the Analog Acquisition function set provided standard with every TAURUS ONE system. Internally, the code will be modified so as to be less flexible but more efficient. This will result in a minimum scan time of 2 milliseconds for 16 analog input channels at a gain of 1. The function syntax used to set up this will be similar to that of the start functions included in every TAURUS ONE/10.

The function will operate so that acquisition will begin upon the assertion of a particular bit on the digital input of the TB571. The acquisition will continue only as long as this bit is asserted. This results in data only being stored for the length of the test time. A total of 650 readings may be stored in the unit.

6.0 Slow Monitor System

The slow monitor system is shown in diagram form in Figure 11. This system is practically identical in function to the monitor system described in the previous section. This system is designed to interface to 10 K-type thermocouples as well as a number of digital points designed to return valve status. Because of the conversion time of the thermocouples, this system cannot acquire the data as quickly as its fast monitor counterpart. Figure 12 shows where this system monitors points in the control system.

The hardware used is the same as previous systems used, with the exception of the termination panel - T-8941T. This panel is used to interface to 16 thermocouples directly. It contains the temperature sensor to allow for cold junction compensation to take place in the software.

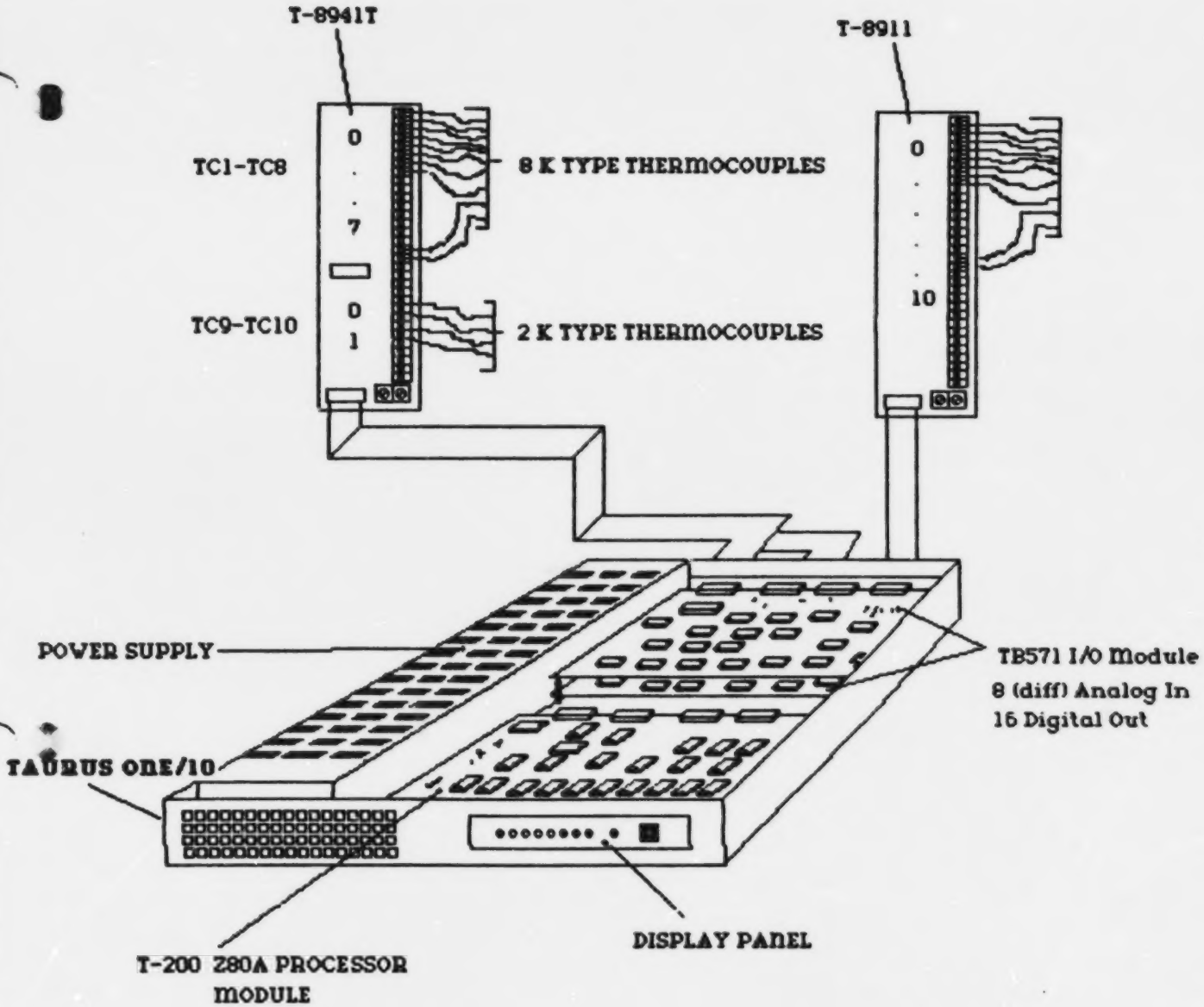


FIGURE 11 - SLOW MONITOR SYSTEM - BLOCK DIAGRAM

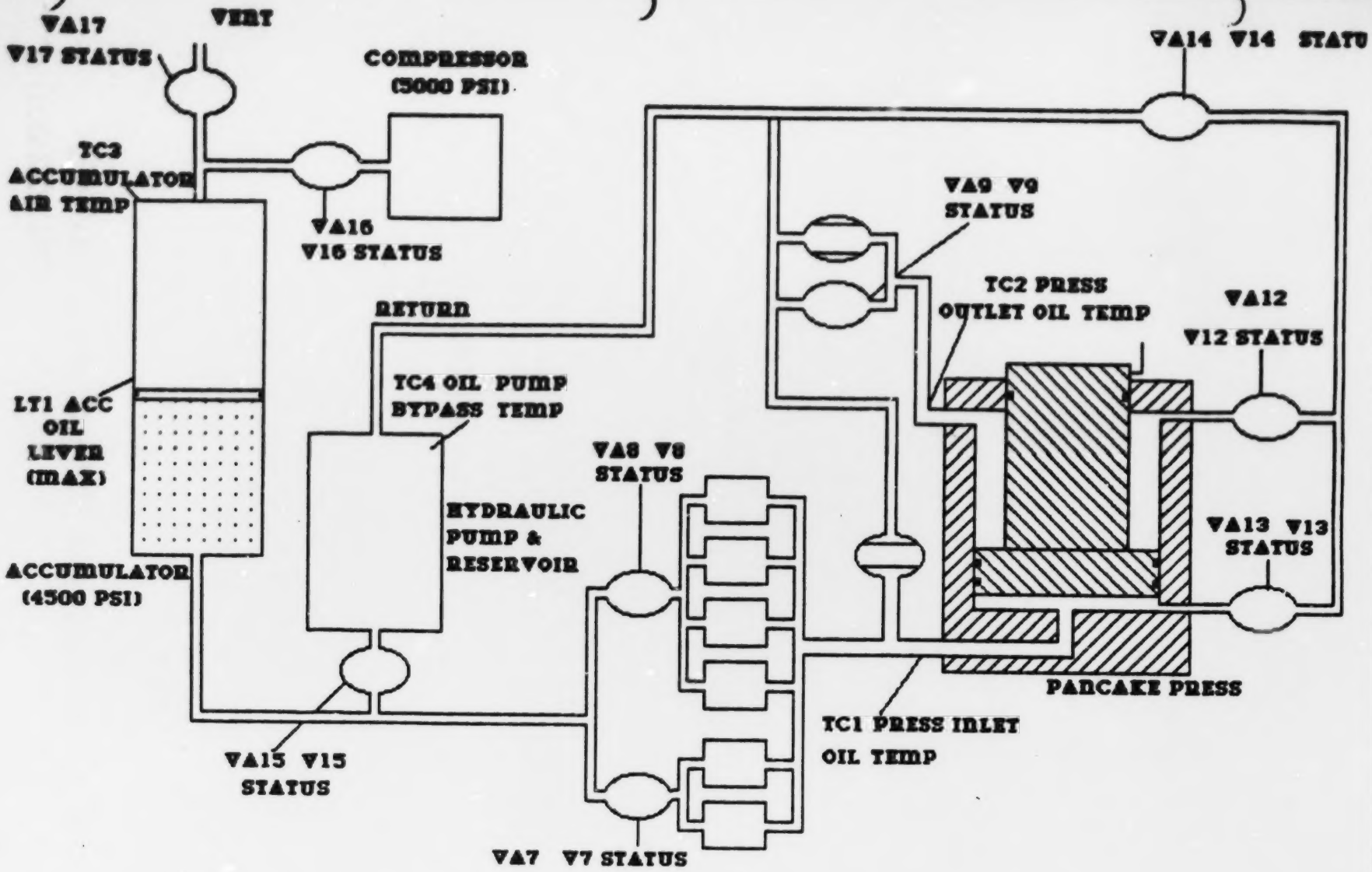


FIGURE 12 - SLOW MONITOR SYSTEM - MONITOR POINTS

Functionally, the two systems are identical. However, the host will set up this unit with much longer timing intervals than with the monitor system. The minimum interval will be 15 milliseconds with up to 810 readings available for storage.

7.0 Host System

7.1 Configuration

Although the host computer will be required to calculate all of the data to be used by the control system during the test run, the computing requirements for the system are not particularly great. This is because all the calculations which must be made do not have to be done in real time, but are done before the test is even initiated. For this reason a small system will be suitable for this application. Any number of systems could be configured to do this job. This proposal is based on a Professional 350 from Digital Equipment. It is felt that the personal computer is suitable for this task environment.

The Professional 350 is a single user system based on Digital Equipment's well-established PDP-11/23 processor. This system includes memory management and 512K Bytes of memory. The system has been configured with a 10 megabyte 5-1/4" winchester disk to provide ample storage for historical test data. The system also has been configured to include a monochrome graphics monitor with a low-profile detachable keyboard.

7.2 Software Environment

The unit uses Digital's P/OS operating system. This is a personalized version of Digital's RSX-11/M-+ minicomputer operating system modified for single users. The application may be developed in FORTRAN-77. This is an extended implementation of the ANSI subset FORTRAN-77 standard (x3.9-1.978).

7.3 Application Program

The application program will be running the entire press control system. It will send out the required set up functions to the various remote units as required. It will gather data from these after test completion. This program is best described by stepping through a sample test session, reviewing the actions of the host and the operator.

6.0 Signals

The following is a summary of the signals involved in this system. This summary lists the signals as expected by the TAURUS equipment.

Control System

Taurus Module	Taurus Chan #	Host Desig. No.		Description
TB571				
(AI)	0	5	LVDT	Ram Position
	1	9	PT4	Press Inlet Pressure
(DI)	0	38	VPSi	Saftey Circuit Status
(DO)	0	31	V7	Inlet Flow Iso - small
	1	32	V8	Inlet Flow Iso - large
	2	33	V9	Outlet Flow Isolation
	7			Test Trigger
TB586				
(AO)	0	21	V1	Flow Cntrl Valve-small
	1	22	V2	Flow Cntrl Valve-large
	2	23	V3	Prop Control Valve
	3	24	V5	Prop Control Valve
	4	25	V4	Prop Control Valve
	5	26	V6	Prop Control Valve

The Control System has four different types of I/O summarized as follows:

Type	Range	Resolution	Spares
(AI) Analog Input	0 V - +10 V	2.44 mV/bit	6 chan
(DI) Digital Input	TTL		7 bits
(DO) Digital Output	TTL		4 bits
(AO) Analog Output	-10 V - +10 V	4.88 mV/bit	none

Fast Monitor System

Taurus Module	Taurus Chan #	Host Desig. No.		Description
TB571				
(AI-1)	0	6	PT1	Accumulator Oil Press
	1	7	PT2	Low F1 Pop Dstr Press
	2	8	PT3	Hi F1 Pop Dstr Press
	3	27	PT4	Ram Hydraulic Press
	4	10	PT5	Press Outlet Pressure
	5	11	PT6	Accumulator Air Press
	6	28	LVDT	Ram Position
(DI)	0			Test Trigger
T-3764				
(AI-2)	0	1	LC1	Force on Billet
	1	2	LC2	Force on Billet
	2	3	LC3	Force on Billet
	3	4	LC4	Force on Billet
	4	12	SG1	Strain Die
	5	13	SG2	Strain Die
	6	14	SG3	Strain Press - New
	7	15	SG4	Strain Press - New
	8	16	SG5	Strain Press - New
	9	17	SG6	Strain Press - Old
	10	18	SG7	Strain Press - Old
	11	19	SG8	Strain Press - Old
	12	51	VA1	V1 Feedback
	13	52	VA2	V2 Feedback
	14	53	VA3	V3 Feedback
	15	54	VA4	V4 Feedback
	16	55	VA5	V5 Feedback
	17	56	VA6	V6 Feedback

	Type	Range	Resolution	Spares
(AI-1)	Analog Input	0 V - +10 V	2.44 mV/bit	1 chan
(AI-2)	Analog Input	-10 V - +10 V	4.88 mV/bit	14 chan
(DI)	Digital Input	TTL		15 bits

Slow Monitor System

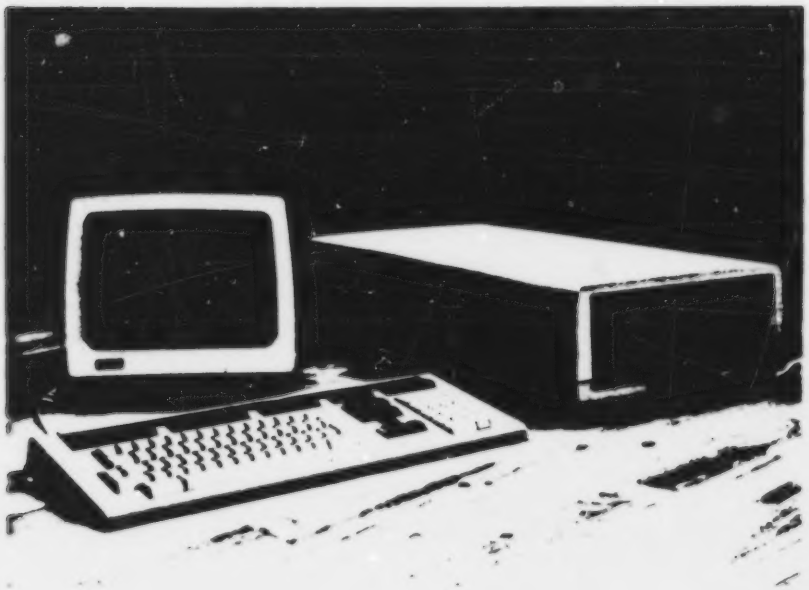
Taurus Module	Taurus Chan #	Host Desig. No.		Description
T-TB571				
(AI)	0	41	TC1	Press Inlet Oil Temp
	1	42	TC2	Press Outlet Oil Temp
	2	43	TC3	Accumulator Air Temp
	3	44	TC4	Oil Pump Bypass Temp
	4	45	TC5	Billet Temp
	5	46	TC6	Billet Temp
	6	47	TC7	Billet Die Temp
	7	48	TC8	Press Seal Temp
(DI)	0	34	LT1	Acc Oil Level - Max
	1	57	VA7	V7 Status
	2	58	VA8	V8 Status
	3	59	VA9	V9 Status
	4	60	VA12	V12 Status
	5	61	VA13	V13 Status
	6	62	VA14	V14 Status
	7	63	VA15	V15 Status
	8	64	VA16	V16 Status
	9	65	VA17	V17 Status
	10			Test Trigger
T-TB571				
(AI)	0	49	TC9	Furnace Temp
	1	50	TC10	Furnace Temp

Type	Range	Resolution	Spares
(AI) Analog Input	+/- 49.75 mv	2.44 mv/bit	6 chan
(DI) Digital Input	TTL		21 bits

A.1 Data Acquisition and Control Equipment - Taurus Computer Products Inc.

THE PROFESSIONAL 350 Digital's High Performance 16 Bit Workstation for OEMS

digital



The Professional 350 is a powerful, low cost workstation suitable for a variety of OEM applications. The 350 is based upon the PDP-11/23 Plus microprocessor and comes with mass storage, graphics, communications, and software options to provide extensive processing capabilities.

System Unit Features:

- Single User
- 11/23 Plus CPU with Floating Point Accelerator
- Memory Management
- 512 KB Memory Standard — Expandable to 1 MB (in 256 KB increments)
- 22 Bit Memory Addressing
- 2 Serial Lines (Std)

Integral and Add-On Storage

- 800 KB (2 × 400 KB) 5¼" Diskette Drives
- 5 MB 5¼" Winchester Disk
- 10 MB 5¼" Winchester Disk

Add-On Hardware Options

- 960 × 240 Pixel Monochrome Graphics
- 960 × 240 Pixel Color Graphics (8 colors out of 256)
- Low profile, detachable keyboard
- Real Time Interface
  - IEEE-488 Interface
  - Parallel I/O Port
  - 2 Serial I/O Ports
- Ethernet Controller
- Local Network Interconnect
- Mini-Exchange Communication Port Switch
- Telephone Management System
- IVIS — Interactive Video Information System
- DECtalk
- CP/M Option Module

Software Support

- P/OS (RSX-11 Compatible), RT-11, and VENIX (Unix environment) for real time Applications
- P/OS, RT-11, UCSD p-System, VENIX, and CP/M for Program Development or Business Applications
- CP/M and VENIX for Industry Standard Operating System Environments
- RSX-11M and VMS Development Environments on PDP-11s and VAXs

Workstation Capabilities at a Personal Computer Price

- Low Cost Hard Disk Systems
- OEM quantity discounts available
- Special discount amendments to standard contracts available

OEM Flexibility

- Table and Floor Stand Installable
- 3 Option Slots available on the CTI bus
- 11 Hardware Options Available
- Choice of Bit Map Monochrome or Color Graphics
- Ethernet interconnect to other systems
- Switchable Universal Power Supply

Applications

The Professional 350 can be used as a standalone workstation, as a node in a distributed processing environment, or as an intelligent terminal connected to other computer systems.

As a standalone workstation, the Pro 350 can be connected to instruments, sensors, robots, and other external devices to provide a powerful data acquisition system or real time controller. It can also be used as a graphics system to display diagrams, engineering drawings, and images or can be connected to the Interactive Video Information System (IVIS) or the Telephone Management System (TMS) to control video or voice information.

As a node in a distributed processing environment, the Pro 350 can run applications on its own and then pass or obtain information to or from other systems linked via the Ethernet local area network or serial lines. The Pro 350 may be connected to other Digital systems, such as PDP-11s, VAXs, DECsystems 10s or 20s, to other supplier's computer systems, or to specialized nodes such as file, database, or print servers.

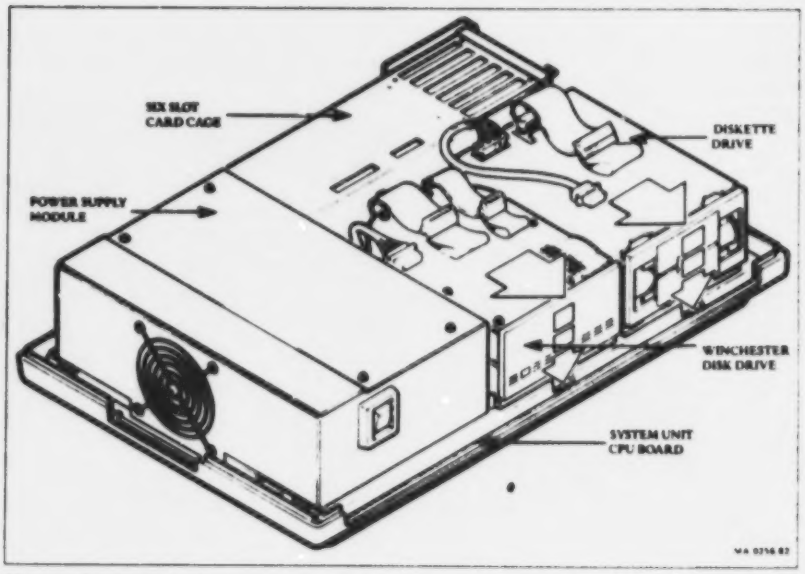


Figure 1. Pro 350 Internals

The Pro 350 can also be used as an intelligent display terminal when attached to other Digital computers in terminal emulation mode. With the PRO/Communications software product, the 350 can emulate a VT52, VT102, or VT125 display and communicate asynchronously with a host system. This allows the Pro 350 to either interact with applications on the host system or be logically disconnected and used as a standalone workstation for off-line processing.

Description

The Pro 350 consists of a base system unit and a selection of add-on hardware options. The system unit houses the central processing unit module which includes the PDP-11/23 Plus microprocessor, a floating point accelerator, 512 KB of main memory, an RS 232 asynchronous/synchronous communications port, and an RS 232/423 serial printer port. Up to 2 additional 256 KB memory cards can be added to increase the Pro 350's main memory to 1 MB.

System storage includes integral dual 400KB 5¼" diskette drives and a choice of either a 5 or 10 MB 5¼" Winchester Disk.

Hardware Options

Hardware Options for the Professional 350 include a low profile keyboard, a monochrome or color graphics subsystem, a Real Time Interface module, an Ethernet controller and a CP/M option module. Also included are the Local Network Interconnect, the Mini-Exchange Communication Port Switch, the Interactive Video Information System (IVIS), the Telephone Management System, and a system unit floor stand.

Keyboard

The Pro 350 keyboard is a low profile, detachable device suitable for most processing environments. It features a control microprocessor, 105 texture-finish, concave surface keys (36 function keys, 18 numeric keys), powerup self diagnostics, and 16 country kit options.

Monochrome Monitor

The monochrome video monitor is a 12" 960 × 240 pixel antiglare display that is available with either a white, green, or amber phosphor. It supports full and split screen smooth scroll, double height lines, double width characters, memory mapped video, and variable intensity. It connects to the system via a standard RS-170 composite video connection.

Color Graphics

The color graphics option is a graphics system to be used as an alternative to the monochrome monitor. The color graphics system uses the same single bit plane video controller as the monochrome monitor, but also requires an extended bit map card for color information. The color system supports up to 8 displayable colors selected from a palette of 256 colors. The color monitor is a 13" display with a resolution of 960 × 240 pixels.

Real Time Interface Module

The Real Time Interface (RTI) module is a single card interface for connecting external devices to the Pro 350. It is useful for connecting lab or test instruments, sensors, motors, and actuators to the 350 to provide a low cost, real time controller. It features a 1978 Standard IEEE-488 General Purpose Instrument Bus, two EIA RS 232/423 serial asynchronous ports (50 to 9600 baud; separately selectable), and 24 bidirectional parallel I/O lines.

Each RTI function can be used separately, in combination, or simultaneously. A convenient RTI connector pod provides all of the internal connections necessary for the RTI and is required when more than one function is used concurrently. Single function connector cables for each module are also available.

High level software support for the Real Time Interface is available in the PRO/Tool Kit RTI Library. This optional software provides subroutines callable from PRO/Tool Kit languages, including Fortran-77 and Basic-Plus-2. The RTI can also be programmed using Macro-11 and the PRO/Tool Kit.

Ethernet Controller

The Ethernet Controller is a low cost Local Area Network interconnect for the Pro 350. The controller connects to the H4000 Ethernet Transceiver or the Local Network Interconnect to give the Pro 350 access to other PDP-11, VAX, or Pro Series systems. Ethernet is a 10 MBit/sec Local Area Network.

Local Network Interconnect

The Local Network Interconnect (LNI) is an inexpensive device for connecting up to 8 Ethernet devices in a local cluster. Devices can be connected together in a 50 meter radius and the LNI can be attached to either a coaxial cable or another LNI. The LNI is ideal for connecting together a number of closely situated workstations in an office or laboratory environment.

Mini-Exchange Communication Port Switch

The Mini-Exchange Communication Port Switch is a low cost communications device for connecting up to 8 asynchronous devices in a local cluster. The Mini-Exchange has 8 ports which can be connected to any RS 232/423 device, including modems. Devices can be attached within a 200 foot radius and can transfer at data rates ranging from 300 to 19,200 bits per second.

CP/M Option Module

The CP/M option module is available for OEMs who want to offer industry standard business applications. The CP/M card has a separate microprocessor with up to 64 KB of RAM memory. CP/M will allow access to popular CP/M applications such as spread sheet and word processing.

Interactive Video Information System (IVIS)

The Interactive Video Information System (IVIS) is a sophisticated subsystem that allows video information from a two channel video disc player to be displayed on the monochrome or color graphics monitor. IVIS is ideal for training applications and can be used with graphics commands to enable sophisticated video images with graphic or text overlay.

Telephone Management System

The Telephone Management System is a powerful voice management system for the Pro 350 and other DEC systems. TMS allows voice communications to be compressed by voice encoding techniques and then stored on disk for later access. It is useful for applications where operation instructions need to be left at an unmanned site and then accessed by an operator who will use them later.

The Telephone Management System includes the Telephone Management Module and the Telephone Management Voice Unit. The Telephone Management Module includes four jacks (for 2 telephone lines), a local telephone handset, and a codec (coder/decoder) for voice signals. The Voice Unit includes a speaker, a touchtone telephone pad, voice dictation function keys, and a dictating machine.

DECtalk
DECtalk is a voice synthesis unit that verbalizes ASCII text information transmitted from a computer or workstation. DECtalk accepts a text string from either the keyboard or a program and then speaks the information in a variety of voice types and speeds. DECtalk is an ideal tool for communicating operating and control instructions as well as for imparting educational or training information.

Floor Stand
The Professional 350 floor stand is an enclosure for vertically mounting the system unit into a deskside package. It is a hollow floorstanding shell into which the Pro 350 system unit inserts.

Operating Systems
The Professional 350 is based upon a PDP-11 microprocessor and its operating environment is compatible with Digital's primary PDP-11 and VAX systems. These programs provide the optimal environment for applications ranging from program development to real time or commercial business applications. In addition, industry standard operating systems are supported to allow easy program migration to the Professional 350 from other vendor's systems. Table 1 summarizes the operating systems appropriate for different technical applications environments. A variety of programming languages are available including FORTRAN, PASCAL, C, and BASIC.

Application Need	Operating System
Real Time	
• Foreground/Background	RT-11
• Multitasking	P/OS, VENIX
Program Development	RT-11, P/OS, VENIX, UCSD p-system, CP/M
Application Portability to Other PDP-11s and VAXs	RT-11, P/OS
Small Memory System	RT-11
Unix Environment	VENIX
CP/M Environment	CP/M
Communications/Networking	P/OS, RT-11, VENIX
Commercial Systems	P/OS, RT-11, VENIX, CP/M

Table 1 Operating System Products

Development Tools
The Professional Series Developer's Tool Kit provides a program development environment for the Pro 350 on other Digital systems using either VAX/VMS, RSX-11M, or RSX-11M-Plus and on the Pro 350 itself. Programs for the 350 can be developed on a multiuser system and then transported to the 350 via Ethernet, serial lines, or diskettes.

Applications Sofrware
PDP-11 and industry standard application programs, tools, and utilities exist for the operating systems available on the Professional 350. The number of applications available vary dependent upon operating system chosen and are listed in the Professional Series Software Catalog.

Reliability
Built-in diagnostics self-test the Professional 350 CPU, memory, mass storage and keyboard every time it's powered up. Each module installed in the 350 has its diagnostics stored in its own on-board ROM. At system startup, each module sequentially transfers its diagnostics to system RAM, where it is run by the Pro CPU. Errors are shown on the system monitor using bit mapped graphics. Consequently, downtime is minimized, service calls reduced, and maintenance costs slashed.

Maintainability
The Professional 350 was designed to be user maintainable. Failing system components are displayed visually on the graphics monitor. A representation of the Pro 350 system is drawn on the screen and the failing system module is highlighted with reverse video.

All module replacements can be done entirely by hand or with the assistance of simple tools. Cable connections have tether tabs for easy removal and all of the module cards either pull out or are removed after loosening a few thumbscrews.

International Versions
Power cords, keyboards, and native language documentation can be ordered with the Professional 350 for 16 country and language groups.

Ordering Information

See Table 2 for the order numbers of the Professional 350 and options.

Model #	Description
Hardware	
PC350-D2	Professional 350 System Unit
MSC11-CK	256 KB Memory Option
RCD50-A	5 MB Hard Disk Option
RCD51-A	10 MB Hard Disk Option
VR201-A	White Phosphor Video Monitor
VR201-B	Green Phosphor Video Monitor
VR201-C	Amber Phosphor Video Monitor
VR241-AA	RGB Color Monitor (USA only)
VC241-A	Extended Bit-Map Graphics Module
PC3K1-BA	US and Canada Keyboard Kit
PC3K1-CA	US and Canada WP Keyboard Country Kit
PC3XS-AA	CP/M Option Module
PCXXF-AA	PRO 300 Series System Unit Floor Stand
PC3XX-AA	RTI-Real Time Interface Module
PC3XX-AB	RTI Connector Pod (Includes all connectors).
BCC10-03	PRO RTI Y-cable for serial I/O
BCC11-03	IEEE-488 Standard Connector for RTI
BCC12-03	RTI Cable, Parallel I/O
DELNI-AA	Local Network Interconnect
DFMSA-AA	Mini-Exchange Communication Port Switch
DTC11-A	Telephone Management Module
DTC11-B	Telephone Management Voice Unit
PC35V-VB	PRO/IVIS Video Disc System
PC3VS-AA	PRO/IVIS System with Touch Screen
PC3VS-AA	IVIS Option — USA/Canada
PC3VX-AA	Second Sony/Pioneer IVIS Cable
Operating Systems	
QBA13-H3	P/OS on Diskette
QBA02-H3	P/OS on Hard Disk
QBA39-H3	PRO/RT-11 on Diskette
QA718-C3	PRO/VENIX
QA579-C3	UCSD p-System on Diskette
QA112-C3	UCSD p-System on Hard Disk
QA111-C3	UCSD p-System and PASCAL on Hard Disk

Model #	Description
Hardware	
Professional Tool Kits	
QBA14-A3	Pro/Tool Kit
QBA15-A3	Pro/Tool Kit FORTRAN-77
QBA21-A3	Pro/Tool Kit FORTRAN-77 Debug
QBA17-A3	Pro/Tool Kit BASIC-PLUS-2
QBA18-A3	Pro/Tool Kit PASCAL
QBA16-A3	Pro/Tool Kit DIBOL
QBA19-A3	Pro/Tool Kit COBOL-81
QBA58-A3	Pro/Tool Kit RTI Library
Selected Digital Classified Software	
QA113-C3	UCSD PASCAL
QA114-C3	UCSD FORTRAN
QA180-C3	TK! Solver
QA432-C3	MAPS/PRO Graphics
QA442-C3	Mechanical Engineering TK! Solver Pack
QBA04-A3	PRO/BASIC Language
QBA05-A3	PRO/Communications on Hard Disk
QBA25-A3	Applications Starter Kit on Hard Disk
QBA26-A3	Applications Starter Kit on Diskette
QBA45-A3	PRO/Communications on Diskette
QBA47-A3	PRO-2780/3780 Emulator

For a complete listing of Digital Classified Software for the Professional 350, please refer to the following documents:

EJ-30162-55	Professional Series Software Catalog
EA-01735-20	Professional Series Quality Software Portfolio
EJ-30357-59	Personal Computer Buyer's Guide
ED-25804-71	Personal Computer Catalog
EJ-30163-55	Professional Series Ordering Information

Table 2. Ordering Information

Related Publications	
EA-01735-20	Professional Series Quality Software Portfolio
ED-25804-71	Personal Computer Catalog
EE-23781-38	Professional 300 Series Application Developer's Buyers Guide
EJ-30161-55	Professional Series Systems & Options
EJ-30162-55	Professional Series Software Catalog
EJ-30163-55	Professional Series Ordering Information
EJ-30357-59	Personal Computer Buyer's Guide
EK-PC350-TM	Professional 300 Series Technical Manual

Table 3. Related Publications

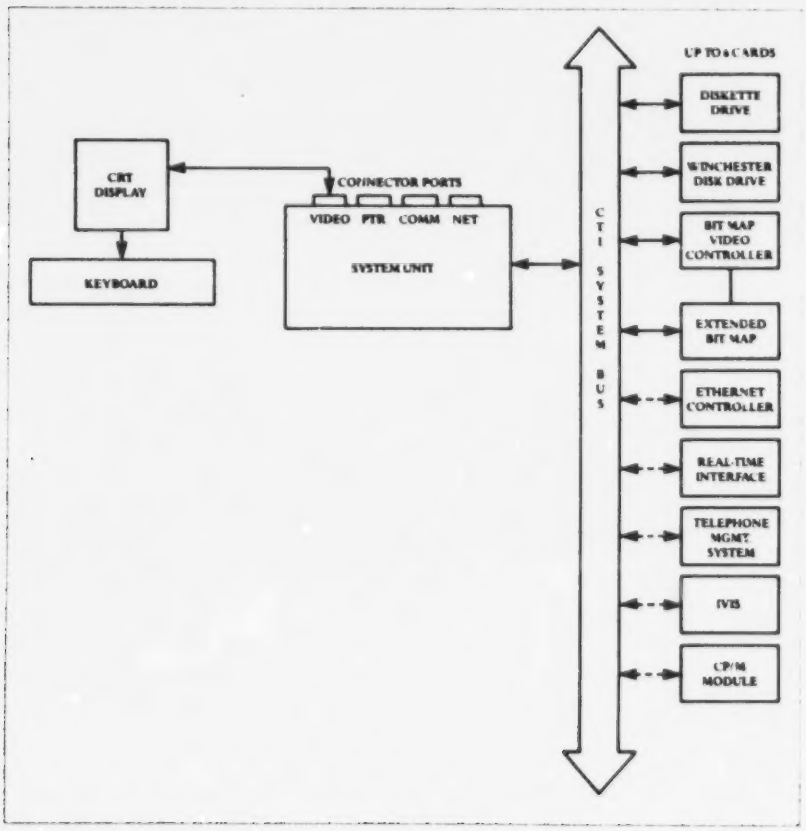


Figure 2. Functional System Block Diagram

System Unit and Power Supply Specifications

Microprocessor:	F11 (PDP-11/23)	
Physical		
Dimensions:	Height	6.5 in (16.5 cm)
	Length	22 in (55.8 cm)
	Width	14.3 in (36.3 cm)
	Max. Weight	35 lb (15.9 kg)
Electrical		
Power Supply Type:	Transistor, switch-type AC to DC converter	
AC Input:	Switch Selectable	
115 V Nominal	Single Phase, 3 wire 90-128 V RMS 47-63 Hz line frequency	
230 V Nominal	Single Phase, 3 wire 274-256 V RMS 47-63 Hz line frequency	
Line Current:	6A@115 VAC 4A@230 VAC	
Regulated Voltages:	+ 5V, + 12V, and − 12 V DC	
Power Consumption:	320 Watts maximum	
Circuit Protection:	Circuit Breaker, externally accessible	
Diagnostics:	Built in powerup tests, displays text messages	
Environmental		
Temperature	− 10° to 40°C (50° to 104°F)	
Humidity	− 20% to 80% relative humidity	
Maximum Wet Bulb	25°C	
Maximum Dew Point	2°C	

Keyboard Specifications

Electronics:	8 bit Microprocessor 4 KB ROM 512 KB RAM 4 LEDS
Physical Description:	Low profile, detachable
Height:	2.0 in (5.0 cm) at highest point
Length:	21 in (53.3 cm)
Width:	6.75 in (17.1 cm)
Weight:	4.5 lb (2 kg)
Keypad:	Sculptured key array
Home Row Key Height:	1.18 in (30mm) above desktop
Keys:	105 matte textured-finished keys Concave surface
Numeric Keypad:	18 keys
Function Keys:	36 keys; firmware and software driven 20 function keys horizontally positioned beneath label strip
Diagnostics:	Powerup self test. Generates identification code upon passing test

International Keyboards:

Australia	France	Norway
Belgium	French Canadian	Spain
Canada/UK	Germany	Sweden
Denmark	Holland	Swiss French
Finland	Italy	Swiss German
US		

Mass Storage Specifications

Feature	RX50	RD50	RD51
Storage Type	Diskette	Winchester	Winchester
Formatted Storage Capacity per Drive	2 × 400 KB	5 MB	10 MB
Avg Access Time (Milliseconds)	290	170	93
Transfer Rate per Second	31 KB	625 KB	625 KB
Avg Seek Time (Milliseconds)	164	170	85
Avg Latency (Milliseconds)	100	8.33	8.33

Table 4. Professional 350 Specifications

The following are trademarks of Digital Equipment Corporation:

Digital Logo	Professional 350
DECtalk	P/OS
DECSYSTEM-20	PDP-11
DECsystem-10	PDP-11/23
CTI bus	PRO/Communications
RSX-11	PRO
RSX-11M	VAX
RT-11	VMS
Mini Exchange	VT
TMS	

Other trademarks include:

UNIX (Bell Laboratories)
UCSD p-System (SofTech Microsystems, Inc.)
TK!Solver (Software Arts, Inc.)
VENIX (VenturCom)
CP/M (Digital Research Inc.)
Ethernet (Xerox)
MAPS (Ross Systems, Inc.)

Information in this publication is based on specifications believed correct at the time of publication. The right is reserved to make changes in specifications and models as design improvements are introduced.

digital

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TAURUS LAB

PRODUCT OVERVIEW

TAURUS LAB: HELPING YOU IMPROVE LABORATORY EFFICIENCY

TAURUS LAB is a peripheral component for your lab computer that can help you automate data gathering and experiment control.

Currently, a great deal of laboratory data accumulates on chart recorders; or appears on meters and displays and must be manually recorded in lab notebooks. At some time later, this data must then be laboriously hand-entered into a computer system for analysis. Pumps, motors, heaters, and other control instruments are also often controlled by hand.

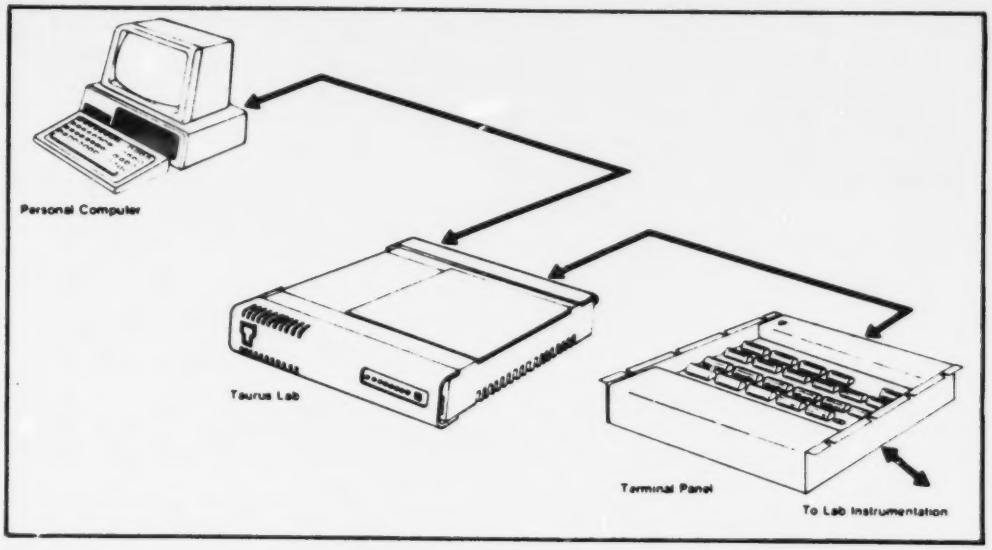
TAURUS LAB can help you bypass these tedious, time-consuming tasks. A microprocessor-based peripheral, TAURUS LAB plugs into any computer system, including the new, powerful personal computers, to allow direct automation of data collection and control.

You can connect variable analog signals from all kinds of lab instruments (such as UV sensors, temperature probes, scintillation counters, etc.) directly to the TAURUS LAB where they are digitized and sent to your computer. Digital on/off or pulse signals are handled with equal ease. Control sequences or output signal levels can then be timed by your computer and executed by the TAURUS LAB. You control this information flow via a series of simple program commands.

If you can program your computer in a language like BASIC, you can start automating your lab today. TAURUS LAB makes it easy.

TAURUS LAB

TURNS PERSONAL COMPUTERS INTO LABORATORY AUTOMATION SYSTEMS



TAURUS LAB is a data acquisition and control front end that converts your computer into a powerful laboratory automation system. The TAURUS LAB internal microcomputer provides a high-level, easy-to-use command protocol that requires no special software or utilities on the host computer to develop a control system. And it plugs into any supported RS232C serial or IEEE 488 communications port on the host computer.

Within a half hour of unwrapping a TAURUS LAB you can write a host program to acquire data or control an experimental event. Several sophisticated TAURUS LAB features make this possible:

ASCII and BINARY command protocols - one for easy access the other for high efficiency.

MULTIPROCESSOR access - up to three host computers can communicate with the TAURUS LAB simultaneously.

MULTIDROP communications - for distributed systems, up to 31 TAURUS LABs can be multidropped on a single communications channel.

DOWNLINE load - users can downline load their own functions and programs for independent execution on the TAURUS LAB.

TERMINAL support - a user terminal can be plugged directly into the TAURUS LAB for direct data access or user program debugging.

THE TAURUS LAB BASIC SYSTEM

TAURUS LAB is a fixed configuration system designed for laboratory applications. The basic package includes the following features:

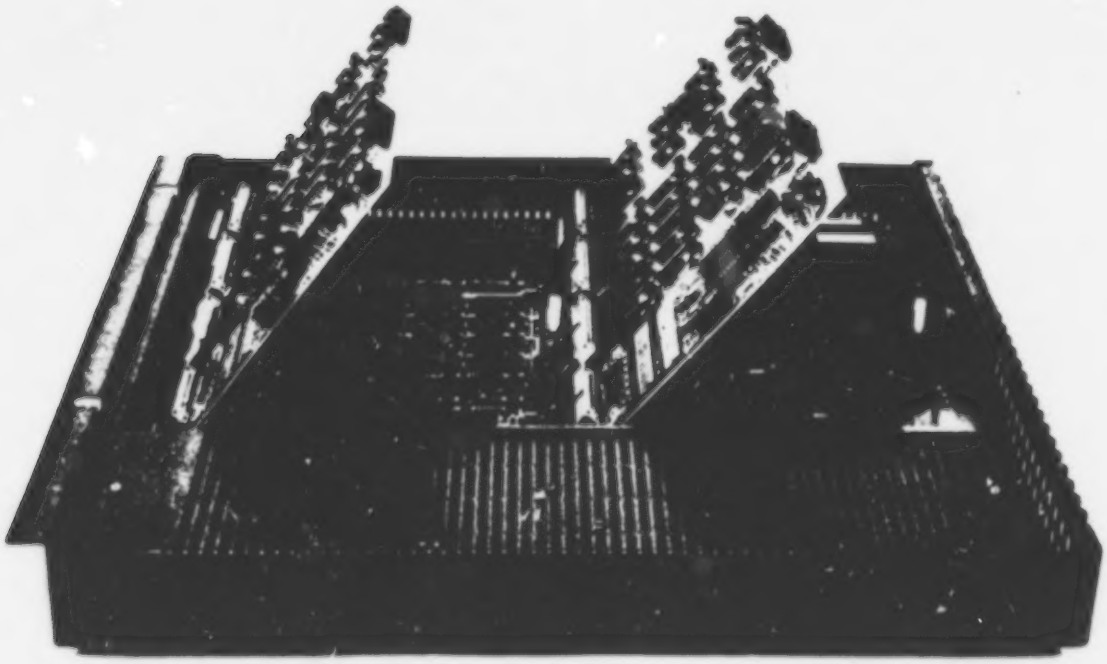
MICROCOMPUTER module (T-200) - this module provides the intelligence of the TAURUS LAB. It is complete with:

- Internal EPROM based software package.
- Twin RS232C serial channels.
- 8K Bytes of user RAM space.
- IEEE 488 GPIB channel.
- Status and display panel.

ANALOG INPUT module (T-3764) - This module provides 64 channels of analog input. Each channel can handle signals from +/- 10mV to +/- 10 volts using any of the four programmable gains. A user may jumper the module for 32 differential or 64 single-ended inputs.

DIGITAL INPUT/OUTPUT module (T-1701) - This module provides 64 points of TTL-compatible discrete inputs or outputs. Each eight bit byte may be jumper-strapped as an input or output.

SLIM LINE enclosure - A rugged, but attractive, case holds up to four Input/Output modules and has its own integral power supply.



WHAT IS INSIDE A TAURUS LAB?

The TAURUS LAB is based on a Z80A microcomputer with an integrated firmware operating system. The various input/output modules communicate with the TAURUS LAB over a special I/O bus.

Command messages from the host computer reach the TAURUS LAB over any of its three communications ports. You simply send a command string with a high level statement like PRINT from BASIC and receive a data string back with an INPUT statement. Decoding programs within the TAURUS LAB firmware interpret the commands and cause one of a number of data acquisition or control function programs to execute under the TAURUS operating system. Each different function returns results to the host computer on the same communications port.

A standard set of functions within the TAURUS LAB firmware allows reading or setting of all signal I/O. For most users, this TAURUS LAB firmware library of functions is all that will ever be needed.

However, since the TAURUS LAB internal firmware is a small operating system, you may write your own special-purpose functions and downline load them to become extensions of the standard TAURUS LAB firmware. Special functions may also be set up to run continually or on a timed basis to allow the TAURUS LAB to off-load the host or run as a stand-alone controller.

Other features of the TAURUS LAB firmware include:

- On-line and off-line diagnostics for system trouble-shooting.
- A Console Emulator program which allows direct interaction with the TAURUS LAB at the machine level for debugging user programs.
- A set of internal system utilities to allow easy programming of user functions.

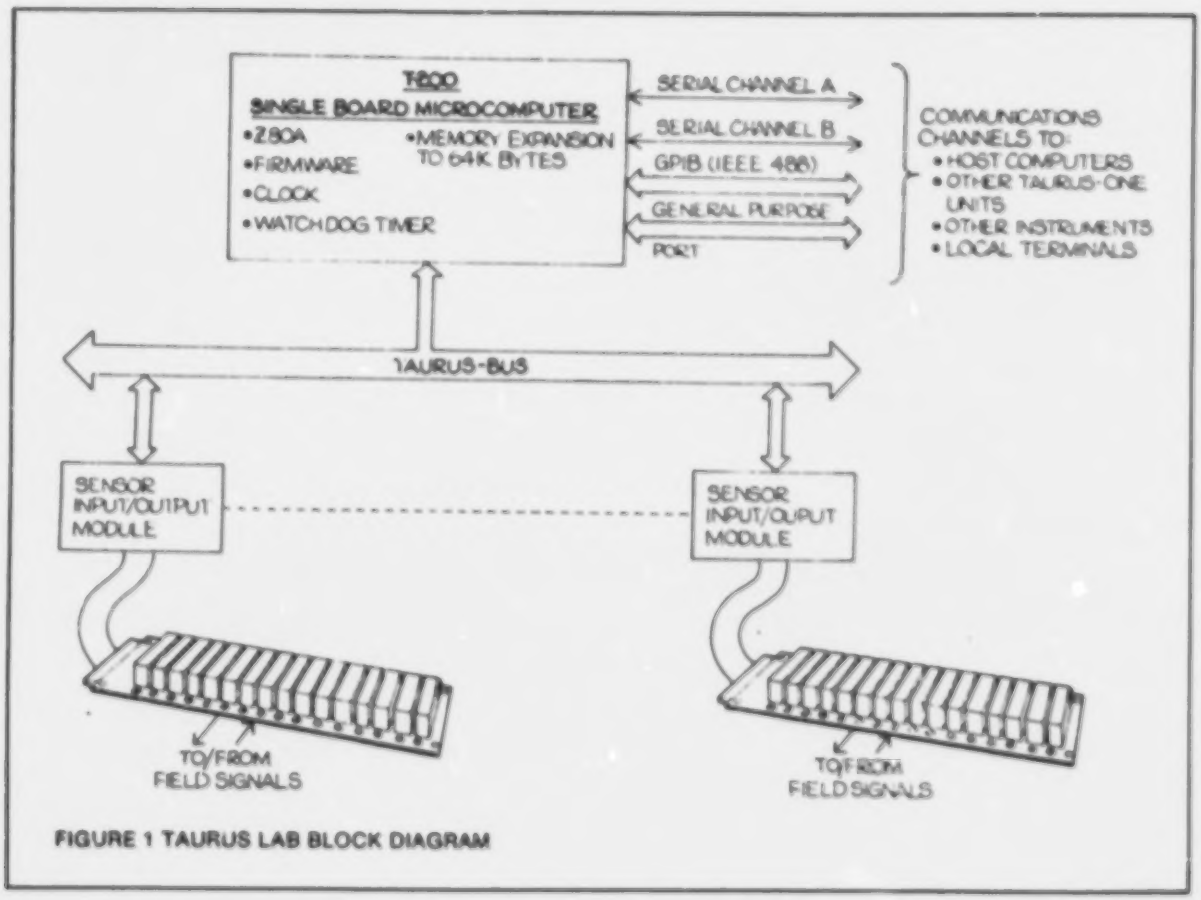


FIGURE 1 TAURUS LAB BLOCK DIAGRAM

THE MICROCOMPUTER

The heart of the TAURUS LAB system is a single-board microcomputer the T-200. This computer, based on a Z80A microprocessor, is equipped with a series of input/output ports (see Figure 1) which communicate with:

- Host Computers - via serial ports.
- Local Terminals - via serial ports.
- Host computers via GPIB.
- Signal Input/Output Modules - via TAURUS BUS.
- Future Devices - via multi-use port.

The TAURUS BUS is a specially-designed process input/output data path which allows you to connect up to 16 sensor and control modules to the TAURUS LAB system. The special electrical characteristics of the TAURUS BUS allow reliable operation over distances up to 10 meters (30 feet) and let you configure large point count systems. Interconnect between modules and expansion boxes is achieved with mass-terminated cables. Each TAURUS LAB expansion box contains its own power supply so that as your system grows with the addition of expansion boxes and I/O modules, power requirements are automatically met.

MICRO-PROCESSOR - The Z80A was chosen for its powerful instruction set and compatibility with many existing systems. The Z80A operates at 4MHz.

MEMORY - The T-200 microcomputer board is equipped with eight memory sockets which allows full memory expansion to 64K Bytes. The bottom bank of four sockets is dedicated to TAURUS LAB firmware and system RAM. The top four sockets permits system RAM expansion, insertion of user EPROM programs or a combination of both. Each socket may be strapped to accept either a RAM or EPROM chip of the Byte-wide format. The TAURUS LAB comes equipped with four 2K Byte RAM chips installed in the top four sockets.

WATCHDOG TIMER - This circuit ensures the microcomputer will be re-initialized in the event of a processor halting or being caught in an infinite loop. A software routine in the TAURUS LAB driver "hits" the WATCHDOG TIMER (WDT) clock periodically. If this routine fails to run, the WDT times out and re-starts the processor.

CLOCK - This crystal-controlled timer generates precision timed interrupts to the microprocessor to allow accurate time keeping and scheduling of programmed events.

SWITCH REGISTER - Sixteen on-board switches allow baud rate and mode selection for serial channels A and B, as well as TAURUS LAB identification for use in multi-drop systems and other optional mode indicators to the on-board software.

INDICATORS - Eight LED indicators provide information on processor status during both normal operation and execution of internal diagnostics.

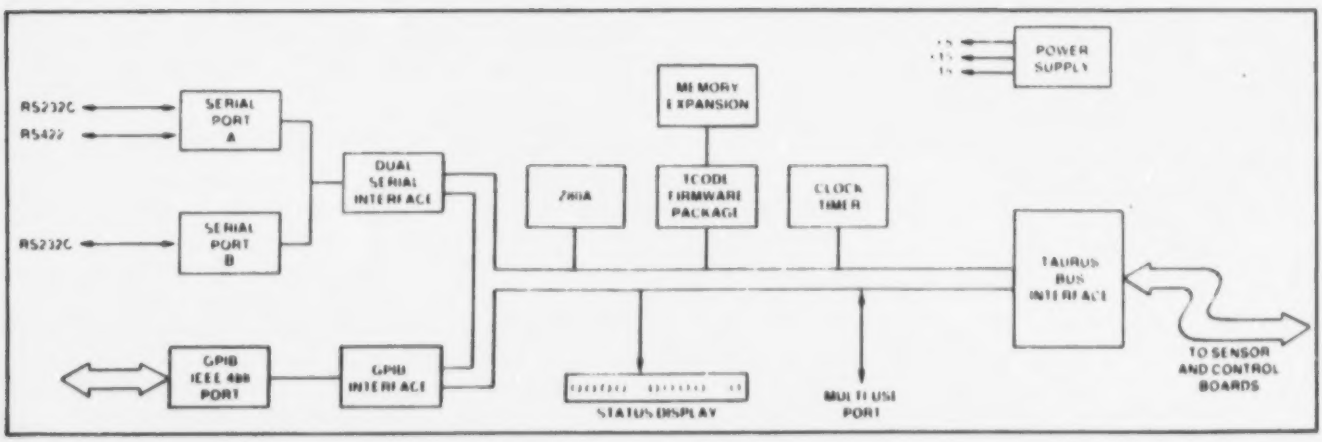


FIGURE 2 - TAURUS LAB SYSTEM BLOCK DIAGRAM

INPUT/OUTPUT PORTS

The following descriptions provide an overview of the characteristics of each TAURUS LAB input/output port.

CHANNEL B - A serial, asynchronous RS232 channel, this channel may be used for communication to a host computer or to a local console terminal. It is equippped with modem control signals. Line speeds of 300 baud to 9600 baud may be selected.

CHANNEL A - This channel is identical to Channel B except that it is equipped with a set of RS422 drivers and receivers which may be used instead of the RS232 signals. The RS422 differential device technique permits reliable data transmission, without a modem, at high rates over longer distances than RS232. It is ideal for communication between TAURUS LAB and the host computer over several thousand feet.

TAURUS BUS - This bus is designed as a simple and reliable interface bus for real world signal modules. The TAURUS BUS is equipped with special line transceivers which make it possible for the bus to expand through multiple TAURUS LAB expander boxes while maintaining reliable operation.

GPIB - This port is the IEEE 488 standard bus for instrument interconnection. It allows the TAURUS LAB to communicate both to a host computer and to other instruments plugged into the GPIB.

MULTI-USE PORT - This port is a buffered access to the Z80A microprocessor bus. It is intended to allow expansion of the capabilities of the T-200 microcomputer for future applications and enhancements.

INPUT/OUTPUT MODULES

The digital and analog signals of your laboratory are handled by input/output modules included in the TAURUS LAB or by modules that may be added as optional expansion. A TAURUS LAB comes in a standard configuration with two I/O modules included as follows:

DIGITAL INPUT/OUTPUT is provided by the T-1701 module which contains 64 discrete points. These points may be selected as input or output in blocks of eight points. Each point is compatible with standard TRANSISTOR TRANSISTOR LOGIC (TTL).

ANALOG INPUT is provided by the T-3764 module which contains a 64-channel analog signal multiplexer, four program-selectable gain instrumentation amplifiers, and a 12-bit bipolar analog-to-digital converter.

The TAURUS LAB enclosure provides mounting space for an optional I/O module which includes two sections:

ANALOG OUTPUT is provided on the T-IO471 module which contains four channels of bipolar signal output, each with its own dedicated output register that provides 12 bits of resolution.

COUNTER INPUT/OUTPUT is also provided on the T-IO471 module which contains seven 16-bit counters. Each counter has its own 16-bit hardware register for pulse accumulation. Four of the seven counters may be programmed for precision frequency measurement or may be used to generate precision output pulses or pulse trains.

Each of these modules is presented in more detail on the following pages.

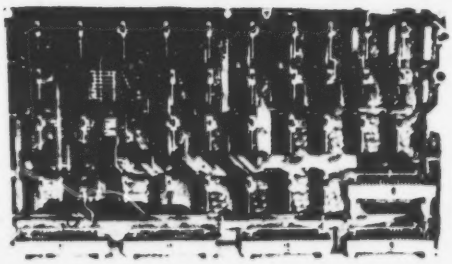
TAURUS COMPUTER PRODUCTS INC.

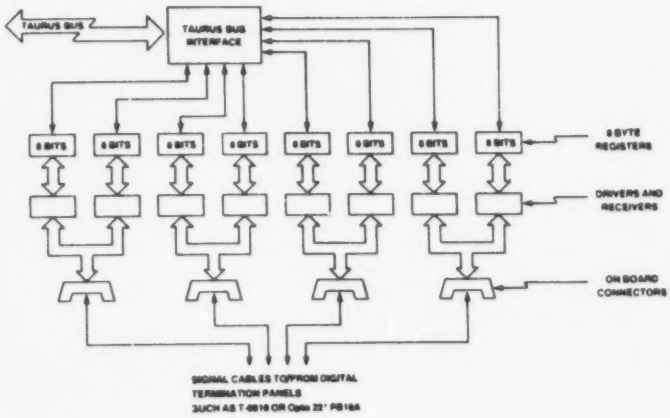
OPTION SPECIFICATION

T-1701

64 Point Digital Input/Output

TAURUS BUS MODULE




TAURUS BUS
TAURUS BUS INTERFACE
8 BITS
8 BYTE REGISTERS
DRIVERS AND RECEIVERS
ON BOARD CONNECTORS
SIGNAL CABLES TO/FROM DIGITAL TERMINATION PANELS SUCH AS T-8910 OR Opto 22* PB16A

The T-1701 is a Taurus Bus module that provides 64 buffered TTL level digital inputs or ou puts. These bits are organized into 8 bit wide registers, each of which is jumper selectable a an input or an output byte. Drivers and receivers on this module are TTL compatible device however, high voltage and high isolation may be obtained using an external isolation panel suc as those manufactured by Opto 22*.

FEATURES

- 64 TTL level input/output points.
- Eight 8 bit digital I/O registers each jumper configured for input or output.
- Contents of output register may read back.
- Input or Output configuration may be read by software.
- Output registers provide 24mA of sink current and 15mA of source current.
- Cables available for connection to T-8910 signal conditioning/screw terminal panel.
- Cables are directly compatible with Opto 22* high voltage/high current isolated signal conditioning panels.

* Opto 22 is a registered trademark of Opto 22, 15461 Springdale Street, Huntington Beach, California.

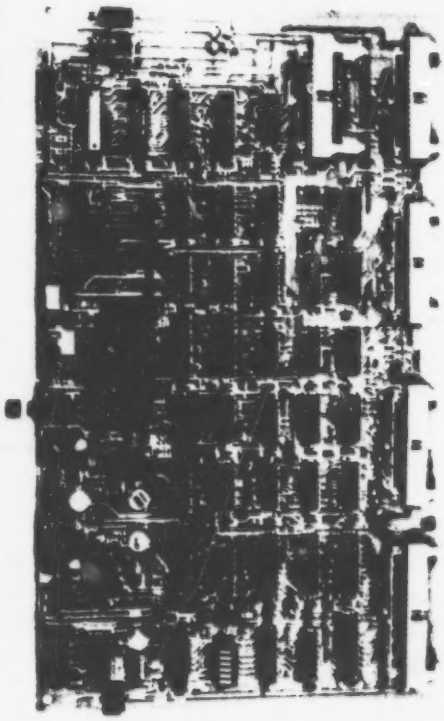
TAURUS COMPUTER PRODUCTS INC.

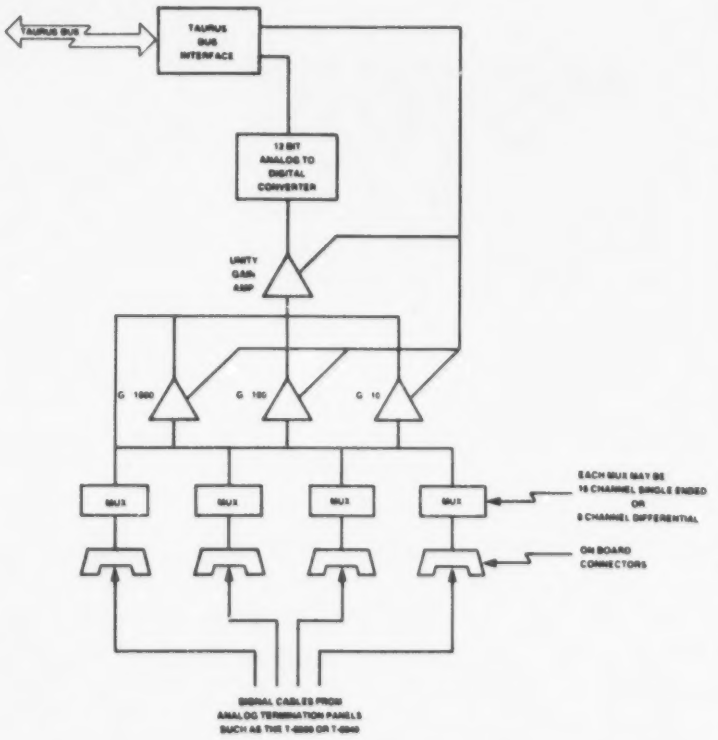
OPTION SPECIFICATION

T-3700 Series

64 Channel Non-Isolated Analog Input Module

TAURUS BUS MODULE





The T-3700 series of Taurus Bus modules provide up to 64 channels of single ended (or pseudo-differential) or 32 channels of differential analog input. Analog input is obtained by selecting one of the input channels using an analog multiplexer and converting the voltage to a digital value with a twelve bit successive approximate analog to digital converter. One of four amplifier gains may be selected for each conversion allowing a full scale input range between ± 10mV to ± 10 volts.

FEATURES

- **64 channels of single ended input or 32 channels of double ended input.**
- **Available in a 32 channel single ended or 16 channel differential version.**
- **12 bit resolution.**
- **System accuracy of .1% full scale.**
- **Standard gains available are 1, 10, 100, 1000.**
- **Conversion time of 50 micro-seconds at low gains.**
- **Successive approximation analog to digital converter.**
- **Converter input range is ± 10 volts. May be user jumpered for ± 5 volts or 0-10 volts..**
- **Cables available for field connection.**
- **Cables connect directly to Taurus analog signal conditioning/screw terminal panels (T-8820, T-8840). These panels provide capability for installation of signal filtering, current loop input, voltage division and surge suppression components.**

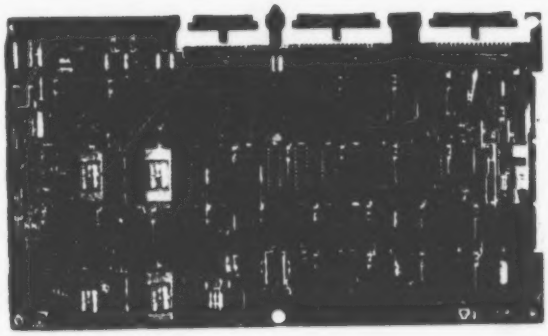
TAURUS COMPUTER PRODUCTS INC.

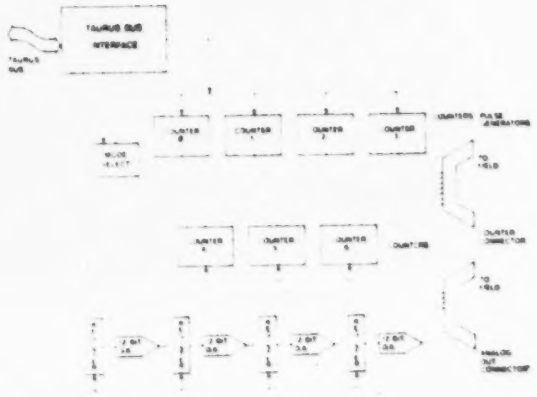
OPTION SPECIFICATION

T-IO470 SERIES

Counter/Pulse Output
Analog Output

TAURUS BUS MODULE





The T-IO470 series of modules provides a mixture of pulse or event counting, frequency measurement, pulse output and analog output.

All versions of this module include seven 16-bit counter blocks. Three of these counters are used exclusively as event counters. The other four counters may be set up, through software commands, as counters to measure frequency, or as pulse output blocks (either finite or continuous pulse streams).

Some versions of this module include four digital to analog converters which provide four channels of analog output voltages.

FEATURES

- **Seven 16-Bit Counters.**
- **8 MHz Input Pulses.**
- **Four of seven Counters may be set up to count events, measure frequency, output pulse streams.**
- **Counter connector is compatible with cable from T-8910 series signal conditioning/screw terminal.**
- **Four 12-Bit digital-to-analog converters (T-IO471 only).**
- **Analog connectors compatible with cable from T-8920, T-8940 series signal conditioning/screw terminal panels (T-IO471 only).**
- **Counter Connector is also compatible with Opto 22* high voltage/high current isolated signal conditioning/screw terminal panels.**

*Opto 22 is a registered trademark of Opto 22

TAURUS LAB OPTIONS

ANALOG OUTPUT AND COUNTERS (T-IO471) - This single module provides four channels of +/- 10 volts analog output and seven 16-bit counters. Four of the seven counters may be selected for frequency input measurement or may be used for precision pulsed output.

SCREW TERMINAL PANEL (T-LAB890) - This attractive termination panel provides high quality screw terminals for all the input/output channels of a TAURUS LAB, including the optional analog output and counters. It also provides a variable voltage source, input push button switches, output transistor drivers and access to the TAURUS LAB internal power supply voltages. Flat ribbon cables connect the T-LAB890 panel to the various I/O modules of the TAURUS LAB system.

TAURUS LAB EXPANSION

The TAURUS LAB may be expanded by the addition of modules and options from the TAURUS ONE product family. This means that in addition to the TAURUS LAB standard system and options a user may add:

- EXPANDER box - holds up to four additional I/O modules. Up to four expander boxes may be added to a TAURUS LAB.
- T-3764 module - 64 analog input channels.
- T-3732T module - 32 thermocouple input module with on-board compensation.
- T-2700 module - two to eight channels of analog output with optional 4-20mA output or +/- 10 volts.
- T-1701 module - 64 digital input/output points.
- T-IO471 module - four analog outputs (+/- 10 volts) and seven counters.
- T-IO472 module - seven 16-bit counters.
- T-711 module - 16 analog inputs and 32 digital input/output points.

. SPECIAL SCREW TERMINAL TERMINAL PANELS

- T-8910 - 16 digital I/O points.
- T-8920 - 16 analog I/O channels.
- T-8940 - 32 analog I/O channels.
- T-8940T - 16 direct thermocouple input channels.

. DIGITAL ISOLATION

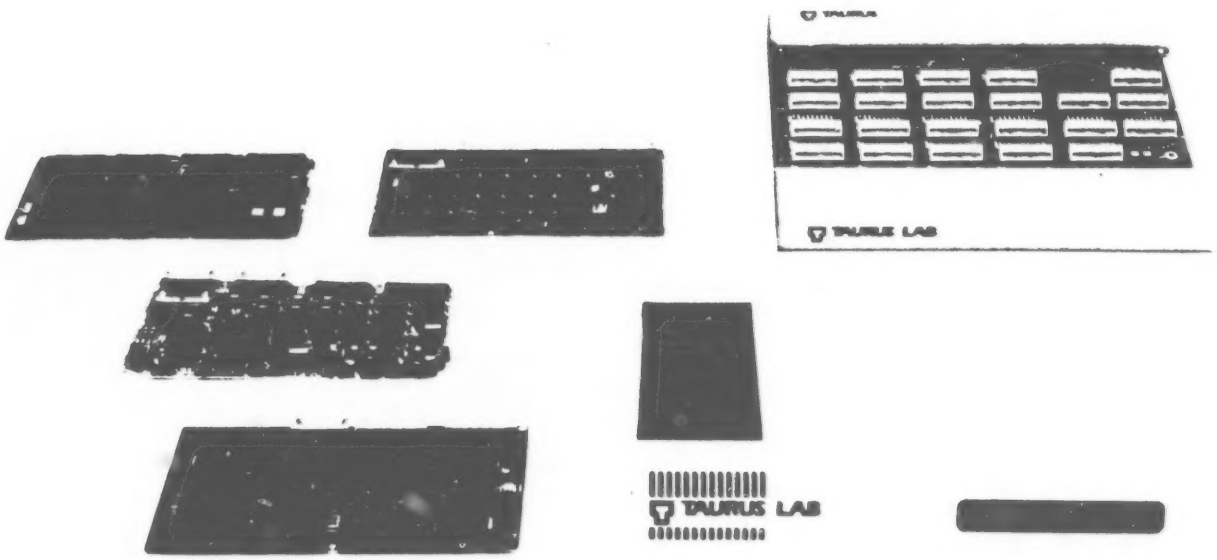
- T-PB16A - Screw terminal panel that accepts up to 16 optical isolator blocks. Each block provides 4000V of optical isolation.

- IDC5 - Single DC input block accepts DC inputs from 10V to 32V.

- IAC5 - Single AC input block accepts AC inputs of 90VAC to 140VAC.

- ODC5 - Single DC output block switches DC voltages up to 60VDC @ 3 amps.

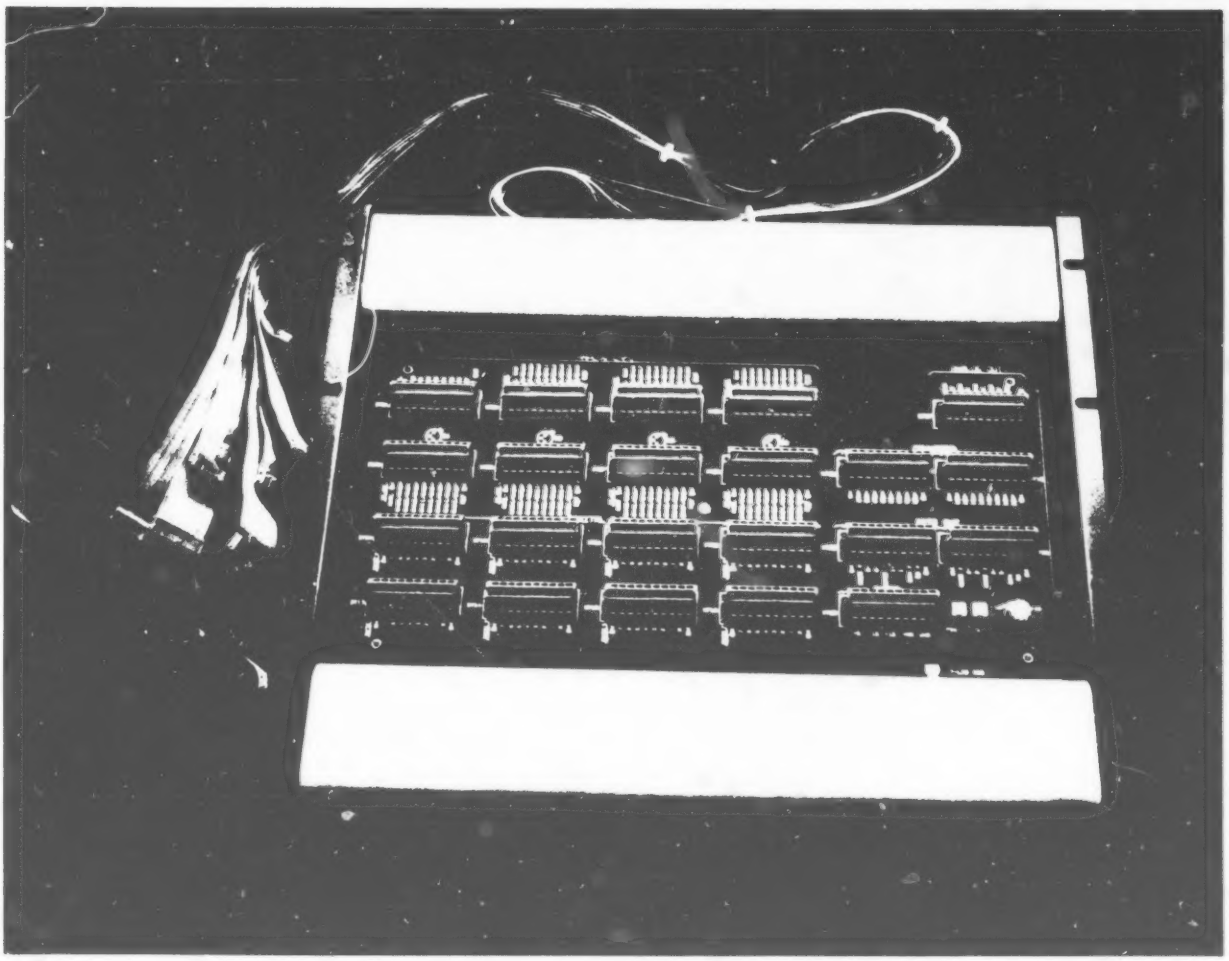
- OAC5 - Single AC output block switches AC voltages of 12VAC to 140VAC at 3 amps.



CONNECTING SIGNALS TO THE TAURUS LAB

Each TAURUS LAB I/O module has a set of signal connectors on its back edge. Field wiring cables with mating connectors may be plugged directly into these on-board connectors and routed out of the TAURUS LAB through the cable access slot on the back of the unit.

For those who prefer the convenience of a patch panel, the T-LAB890 terminal panel provides all the necessary connections.



The T-LAB890 is equipped with convenient tubular clamp terminal points that accept any wire size from #30 gauge to #14 gauge. Connections are provided for all I/O from the T-1701, T-3764, and T-IO471 modules. In addition, the T-LAB890 provides the following convenience features:

- The internal TAURUS LAB power supply voltages are brought out for external use.
- A variable analog voltage is provided for calibration or testing purposes.
- Two push buttons that may be connected to any digital input points and act as a trigger.
- Four optically-coupled output drivers that may be connected to any digital output points and may be used to switch up to 100 milliamps at up to 30 volts.

Flat ribbon cables attached to the T-LAB890 plug into each of the signal connectors on the TAURUS LAB I/O modules.

MOUNTING THE TAURUS LAB

The TAURUS LAB and the T-LAB890 screw terminal panel are designed to become an attractive addition to the lab bench. Both come equipped with rubber feet to eliminate surface scratching or both units may be rack-mounted. The TAURUS LAB can be equipped with optional rack-mount slides which allow it to mount in any standard 19" equipment rack. These slides also let you pull the unit out of the rack for calibration or maintenance.

USING THE TAURUS LAB

Once a TAURUS LAB, with its modules installed, is plugged into a serial or IEEE 488 port on your computer, you are ready to send commands and receive data.

Most people are familiar with BASIC so we will use this language in our examples. However, the principles apply equally to whatever language you may prefer.

All computers are equipped (or can be equipped) with a serial channel so we will use this type of communication port in our examples. The command protocol for an IEEE 488 (GPIB) would be identical. Of course the serial or GPIB channel must be supported by the language system software for the computer used.

The TAURUS LAB accepts command messages as a string of ASCII characters. This is very convenient since most computers have software that supports transmission of ASCII characters along their serial or GPIB communications channels.

Let's start by reading the value of a digital input point. The following BASIC program steps would achieve that result:

```
10      OPEN COM AS #1

20      PRINT #1 "$A0,7,RD BT (0,7)"

30      INPUT LINE #1 "A$,B$,C$"

40      BIT=VAL(C$)

50      CLOSE #1
```

Statement 10 is a typical command to open a communication channel and designate it as #1 (some operating systems include an expression to define baud rates, parity, etc.).

Statement 20 causes the ASCII message

```
$A0,7,RD BT (0,7) <CR>
```

to be sent to the TAURUS LAB as an ASCII character string.

Let's examine each character segment:

$ - tells the TAURUS LAB that a new message is starting.

A - tells the TAURUS LAB that the message is in ASCII format (B would indicate binary format).

0, - tells the TAURUS LAB that there is no error checking characters appended to the message.

7, - identifies the TAURUS LAB unit number (could be 1-31, 0 is a broadcast).

RD - tells the TAURUS LAB that this function command is of the READ group.

BT - tells the TAURUS LAB that this function is a READ BIT.

(0,7) tells the TAURUS LAB that the bit is located in TAURUS BUS address byte number 0, bit number 7.

<CR>- message terminator

The response is captured in line 30 with the INPUT statement. The actual response would be:

!7,0,1 <CR>

where:

! - is a message header.

7, - tells the host that the response came from unit number 7.

0, - tells the host that the function executed OK (if an error had occured an ,E, would have been transmitted to indicate an ERROR).

1 - tells the host that the bit was set, that is the value was 1. It would have been 0 if the input bit was cleared. If an error had occured, an error number would have been transmitted.

<CR>- message terminator

After the INPUT command, the three string variables are as follows:

```
A$ = "!7"
B$ = "0"
C$ = "1"
```

In this example, we will ignore A$ and B$ because we will assume no errors. C$ then is an ASCII string representing the data. The command BIT = VAL(C$) turns the ASCII string held in C$ into a numeric variable called BIT. Now the variable BIT would be used in any mathematical or logical expression.

The CLOSE #1 statement simply closes down the communications channel.

A command sequence to read an analog channel would be as follows:

```
      .
      .
      .
PRINT #1, "$A0,7,RD AN (4,15)"
INPUT #1, A$,B$,C$
VALUE = VAL(C$)
      .
      .
      .
```

The actual response string would be:

```
!7,0,+1024
```

C$ now holds the ASCII string "+1024" and VALUE is equal to the decimal number +1024. The actual value of the response could have been any number in the range -2048 to +2047 which represents the plus and minus full scale swing of a 12 bit analog to digital converter. The number +1024 represents one half of full scale positive.

The (4,15) in the print statement tells the TAURUS LAB that the reading should be taken on channel 15 of the analog to digital converter whose control register is at TAURUS BUS address 4.

Writing a byte of data out to a digital output would be accomplished with the following sequence:

```
      .
      .
      .
PRINT #1, "$A0,7,WR BY (1,255)
INPUT #1, A$,B$,C$
      .
      .
      .
```

This command sets all the bits (255 is the decimal equivalent of FF in hex or all 1's) at TAURUS BUS address 1.

The data string held in C$ is the value of the output byte that the TAURUS LAB has read back after executing the output byte function. This read back provides a check that the exact data was output correctly.

From these examples you can see how easy it is to manipulate TAURUS LAB signal I/O from any high level language (like BASIC) without the need for special drivers or software extensions in the host computer. It is therefore possible to communicate with the TAURUS LAB from any computer system equipped with a supported serial or GPIB channel. In addition, programs written in a high level language can be transported very easily to any other computer that supports the same high level language.

For users who want to write host control programs in Assembler language to achieve high throughput performance, the TAURUS LAB offers a BINARY protocol. All the function commands available in the ASCII protocol are also available in the BINARY protocol.

The following table lists the current function command repertoire of the TAURUS LAB system. New commands are being added regularly to add to the power of the TAURUS LAB. If you don't see what you need, write or phone us and let us know what new functions would be valuable to your application.

TAURUS LAB
Firmware Functions
(V01.20)

COMMAND (PARAMETERS)	FUNCTION
Read Group	
RD BY (A)	Read BYTE at Taurus Bus Address A
RD BT (A, BIT n)	Read BIT n of byte at Taurus Bus Address A
RD WD (A)	Read WORD at Taurus Bus Address A (i.e. Taurus Bus Address A is low byte and Address A+1 is high byte)
RD AN (A, CHANNEL n)	Read ANALOG Channel n at Taurus Bus Address A
RD ID (A)	Read REGISTER IDENTIFICATION of Taurus Bus Address A
RD CF (A)	Read REGISTER IDENTIFICATION of 8 Taurus Bus Addresses starting at A
RD type [NU](A, CHANNEL n)	Read ANALOG Thermocouple Channel n at Taurus Bus Address A. If NU not present, convert to tenths of degrees C based on one of three thermocouple types - J,K,T. If NU present return results directly without linearization.
Write Group	
WR BY (A, BYTE)	Write BYTE into Taurus Bus Address A
WR BS (A, BIT n)	Set BIT n of byte at Taurus Bus Address A
WR BC (A, BIT n)	Clear BIT n of byte at Taurus Bus Address A
WR WD (A, WORD)	Write WORD into Taurus Bus Address A (low byte) and Address A + 1 (high byte)
Downline Load Group	
LD BL (START, END, xx, xx, ...)	Downline load BLOCK of data from memory address START to memory address END. xx are data bytes being loaded.

Downline Load Group (cont'd)

LD FN (CODE1, CODE2, 0, START, END, xx, xx, ...)
Downline load new FUNCTION. CODE1 and CODE2 are ASCII codes of function command letters. Data bytes (xx) will be loaded in memory from START address to END address.

Continuous Function Control Group

AC (xx, xx, xx, ...)	Add to continuous function buffer. xx are arguments and parameters required by function being added.
CC EN	ENABLE Continuous Function execution.
CC DS	DISABLE Continuous Function execution.
CC CL	CLEAR Continuous Function execution buffer.
CC RP (ENTRY)	REPORT on the next continuous function results starting from ENTRY number.

Diagnostic Group

DR AN port (A, START CHANNEL, No. CHANNELS)	Dump a diagnostic report of analog channels on "port". These channels are at Taurus Bus Address A beginning with START CHANNEL and continuing for No. CHANNELS.
DR BY port (A, NUMBER)	Dump a diagnostic report of digital bytes on "port" starting with Taurus Bus Address A and continuing for NUMBER bytes.
DL TB (OUT, IN)	Do a digital loop back test from OUT byte Address to IN byte Address.

High Speed Scan Group

AS [CL] (A, START CHANNEL, No. CHANNEL, {G, COMP})

Set up for high speed scan. Add No. CHANNEL of consecutive channels beginning with START CHANNEL at Address A to Cycle Table. If so specified, conversions will be done with a gain of G and cold junction compensation specified by COMP. If the argument CL is included, the Cycle Table will be cleared before adding any channels.

TS (A, CHANNEL n, TRIG)

Set up a trigger for high-speed scan. A is TAURUS BUS Address for trigger, CHANNEL n is a bit number or analog channel number. Analog channels will trigger on a change greater than TRIG. For digital channels TRIG defines a level or transition.

AR [NU] (No. of BYTES)

Used to retrieve data stored in memory by the analog acquisition scan (AA) function. Data is retrieved using this function successively. No. of BYTES defines the number of bytes to be returned. If NU is specified results will not be returned in engineering units.

AA [port](CYCLE COUNT, INTERVAL,[TRIG])

This will execute an analog acquisition scan of all channels in the Cycle Table. CYCLE COUNT defines the number of such scans desired while INTERVAL defines the interval - in milliseconds - between scans. If TRIG is present, then the scan will only take place after the trigger (as defined by TS function) has occurred. If port is specified, data is dumped out on the port, otherwise data is saved in memory.

Background Checking Group

RC (port) (A, LAST VALUE, M, protocol)
Reports any changes on Address A. LAST VALUE is used to compare to present value. M is a mask of unwanted bits. Specifying port and protocol allows unsolicited reporting of any changes.

Counter Module Support (T-IO470)

EV EN (A, COUNTER n)	Enable event counting at COUNTER n at TAURUS BUS Address A.
EV RD [CL] (A, COUNTER n)	Read event counter at COUNTER n at TAURUS BUS Address A. If CL is present then clear the counter after the read.
FR [NW] (A. COUNTER n, M)	Read frequency at COUNTER n at TAURUS BUS Address A. M defines the units of frequency desired. If NW is present, the frequency measurement will be initiated but the function will not wait for completion.
FR RD [NW] (A, COUNTER n,)	Read previously initiated frequency at COUNTER n at TAURUS BUS Address A. If NW is present the function will not wait for the reading to complete.
PG FL (A, COUNTER n, WIDTH, PERIOD, NUMBER)	Output a finite pulse stream from COUNTER n at TAURUS BUS Address A. WIDTH defines pluse width, PERIOD pulse period, and NUMBER is the number of pulses to be output.
PG ST (A, COUNTER n, WIDTH, PERIOD)	Output a continuous pulse stream from COUNTER n at TAURUS BUS Address A. WIDTH defines pulse width, PERIOD pulse period.
PG SP (A, COUNTER n)	Stop pulse stream from COUNTER n at TAURUS BUS Address A.

Miscellaneous Control

$^C	Puts port into console mode.
^X	Removes Port from console mode. (Console Mode enables echo, and runs Taurus On-Line Debug program to Examine/Change Memory etc.)
IN	Initializes all modules on the Taurus Bus.